A45

The Kent Incorporated Society for Promoting Experiments in Horticulture

ANNUAL REPORT 1961

EAST MALLING RESEARCH STATION

MAIDSTONE

KENT

1st October 1960 to 30th September 1961

COMMONWEALTH MYCOLOGICAL
2 MAY 1962

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GLOSSARY OF PESTICIDES MENTIONED IN THIS REPORT

Common (or chemical) name	*Proprietary (trade) name*
azinphos—methyl	Gusathion, Guthion
captan	Orthocide 50
chlorbenside	Chlorocide
1,1-dichloro-2,2-bis-(4-chlorophenyl)ethane (DDD)	Rhothane
2,6-dichloro-4-nitroaniline (dicloran)	Allisan
dichlorophen	Panacide
didecyldimethylammonium bromide	Deciquam 222
dimethoate	Rogor
dinocap (DNOPC)	Crotothane, Karathane
dinoseb dimethylacrylate	Acricid
dodine acetate	Melprex, Cyprex
endosulfan*	Thiodan
fenson	Murvesco
fluoroacetamide	Megatox, Vitax—F15
O-1-naphthyl N-methylcarbamate (carbaryl)*	Sevin, Murvin
phenkapton	Phenatol
quinoxalinyl-2,3-trithiocarbonate (thioquinox)*	Eradex
2,4,5,4′-tetrachloro-diphenylsulphone (tetradifon)*	Tedion
2,2,2,-trichloro-1,1-bis-(4-chlorophenyl)ethanol	Kelthane
W.P. 155	Wepsyn

Lissapol N, NX, is a commercial non-ionic surface active agent sold as Agral 90.

* These names have been proposed but have not yet been published by the British Standards Institution.

A45

THE KENT INCORPORATED SOCIETY
FOR PROMOTING EXPERIMENTS IN
HORTICULTURE

ANNUAL REPORT

(FORTY-NINTH YEAR)

1961

EAST MALLING
RESEARCH STATION
MAIDSTONE
KENT

1st October 1960 to 30th September 1961

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The correct abbreviation of the title of this Report is :—
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Appointed by the Staff Council of East Malling Research Station:

Miss E. M. Glenn, B.Sc.

† Appointed December 1960.

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E. Vinson, J.P.

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(1st October 1961)

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† New appointment 1960-61.
‡ Field records: also attached Entomology and Plant Protective Chemistry.

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† New appointment 1960-61.
‡ Also **Fruit Storage Investigations** (in collaboration with Ditton Laboratory).

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Assistant Plantations Officer: Miss B. F. Seymour.

Experimental Nurseries : H. R. J. Byford.

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A. Tidy.
M. Cole.

Bradbourne Gardens : N. S. Gibbens.

Workshops : G. G. M. Weller.
F. A. King.
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J. Denyer (41).
E. Wenham (41).
H. Crittenden (38).
E. Hayes (38) (*Caretaker*).
W. Henson (37) (*Fruit Foreman*).
W. Jenner (35).
P. Fulker (25).
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† New appointment 1960-61.

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NATIONAL AGRICULTURAL ADVISORY SERVICE

Accommodated at East Malling Research Station.

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Clerical Assistant : Mrs. D. Nye. (*Part-time.*)

† New appointment 1960-61.

GENERAL DEVELOPMENT AND ACTIVITIES

This year's report of the Committee, the forty-ninth, describes the day-to-day events in the existence of a living Research Station. There have been no breath-taking events, but inevitably during the year there have been occasions for sadness as well as for rejoicing. Attention is drawn to the hundred-and-one ' routine ' tasks that are carried out and the complexities of finance—including the very significant contribution of the Association –to ensure the smooth-running of research, the participation of the staff in world-wide horticultural activities and the efforts that are made to disseminate information as soon as it is obtained.

In contrast to the deluges of the previous year, the summer of 1961 was very dry, but achieved particular notoriety for the latest spring frost experienced in nearly fifty years. Fortunately the Station escaped its worst effects, both as regards the results of research and the produce of the farm. Nevertheless, the Administration were forcibly reminded of the year 1935—when both suffered severely—and suffered severe headaches in consequence.

Obituary

It was with the deepest regret that the Committee learned of the death in February of Alfred Day, who had been a member of the Executive Committee for more than twenty years. Mr. Day will always be remembered here in connexion with hops, but the unobtrusive help he gave to the Farming Sub-Committee in the days when the Research Station first started arable farming on the Bradbourne estate is perhaps not so well known.

We are also very sorry to record the death of Sir David Bowes-Lyon, one of the Trustees of the Development Fund.

During 1961 there have also been losses among members of the research staff (see p. xvii), which the Committee greatly deplore, while a former member of staff, Dr. F. W. Andrews, who did much painstaking work –particularly in connexion with the published Abstract and Index of the Station's Annual Reports—in the face of gradually increasing disabilities, died in March.

Lastly, we must not forget our old friend Dr. Wladyslaw Filewicz, who came to us as a refugee at the beginning of the last war and, with a short interval, has lived here ever since. He passed away in February, mourned by his friends, retaining his interest in all things pertaining to fruit growing, particularly winter hardiness, until the end.

Governing Members

The only change on the governing body has been the nomination by the Kent N.F.U. of Mr. F. J. French to succeed the late Mr. C. T. Miller, whose death was reported last year ; we were pleased to welcome him at the Annual General Meeting. Miss E. M. Glenn was re-elected as the Representative of the Staff Council. When the Governing Members visited the Station on 21st June, a special point of interest was the new underground laboratory where the growing roots of a variety of fruit trees and bushes are being studied. Recent work on bacterial viruses (bacteriophages) was also discussed in relation to bacterial canker of plums and cherries, and fire-blight. In the afternoon the party were informed about improvements in planting material by selection, virus testing and special propagation, including work on loganberries and black currants as well as on the better known Mother Tree Scheme for top fruits.

Committees

In this report it is difficult to pick out any new or outstanding matters dealt with by the Executive Committee and its Sub-Committees during the year. Nevertheless, regular meetings have been held and, as the Minutes show, the agenda were often long and the meetings arduous there being so many day-to-day problems for the committees to consider and assist in solving. These often concerned the programme of research, the dissemination of information and the conditions of service, insurance, and accommodation of members of staff. While such affairs are not usually described at length in this Report, the regular attendance and unselfish service to the Station given by so many Committee members who deal with them is much appreciated.

To foster the liaison with our mother institution, Wye College, Professor H. W. Miles has been appointed a member of the Farming Sub-Committee. At the end of the year we were sorry to receive the resignation of Professor P. F. Wareing, a co-opted member of the Executive Committee, difficulties involved in travelling from Aberystwyth preventing him from attending regularly.

As the Station approaches its Jubilee year, the appointment of an *ad hoc* Sub-Committee to ensure its adequate celebration is worthy of note.

The Trust Land

The whole of the 140 acres of Ditton Court Farm acquired by the Trustees of the Development Fund has now been taken over, most of it having been under the Station's control during the year. The coming winter (1961/62) will see the first experiments to be planted on the 25 acres to be made available for experimental use during the next five years (see Farm Report). Boundaries have been agreed and such matters as footpaths, much of it has been fenced and a cottage at the extreme north-east corner of Calves Leys field has been leased and is now occupied by a reliable member of the farm staff.

It must be reiterated that the development of this 25 acres does not mean an increase in the area of the farm occupied by experiments ; it is to be compensated for by giving a longer rest to land that has borne tree crops for many years. Nevertheless, an aerial photograph of Ditton Court Farm as it was in 1950, which now hangs in the N.F.U. Building, reminds us of the vital need to take the previous history of any land into consideration in planning new experiments, since there is little land in this neighbourhood that has not carried fruit trees or chestnut coppice in quite recent years.

Maintenance

Members who visit the Station seldom see more of the buildings on the estate than the laboratories and parts of Bradbourne House, but even here they must realize how much there is to be done in maintaining these buildings in good condition ; in the greenhouse area alone there are more than thirty glasshouses and other structures, and there are more to come. But this is by no means the whole story ; farm stores, workshops, implement sheds, barns, nursery packing shed, residences of research and farm staff—both on the Station's land and in the neighbourhood—all have to be maintained in good order.

To achieve this, the maintenance staff—under the guidance of the Chairman of the Building Sub-Committee and the Director—are kept fully employed. However, it is not so much the routine tasks of painting and repairs to which the Committee would draw attention, as to some of the improvements and new structures that are gradually and unobtrusively taking shape—to the eventual good of the Station.

A year or two ago the redecoration of the Great Hall at Bradbourne House was referred to, and the skill with which it had been done admired. Now, most of the reconstruction and redecoration of the house has been completed, and the Bureau are in occupation of the rooms in the neighbourhood of the Judge's Passage. Members who knew the house twenty years ago will find it transformed and very fully occupied to-day. Although the façade looks much the same, the rebuilding and adaptation of the stable block still goes ahead, and has made quite spectacular progress during the year. How near parts of this building were to collapse before it was taken in hand will, we trust, never be realized.

Some publicity has been given lately to the underground laboratory, which was recently constructed by the maintenance staff. During the winter trees were planted alongside it, and the first observations of root growth made during the ensuing spring and summer.

While registering their admiration for the work of the maintenance staff, the Committee also wish to draw attention to the contribution of Mr. MacNeill and the greenhouse staff. While, in the main, they are kept busy growing the innumerable plants required for research, much time is also spent on keeping the fabric of the greenhouses in good order—the oldest house still in use was built in 1923—and in the erection of new glasshouses and other facilities. Among the last, the adaptation by the greenhouse staff of an old boilerhouse to new use as fully-equipped growth chambers must be mentioned.

Finally under this heading, though our own staff are not heavily involved, we must record the start of a new project—covered accommodation for farm machinery and for occasional use on Members' Days, towards the cost of which the A.R.C. and the Association are contributing their quota. As we write, the skeleton of this new building is already to be seen in Egham Field.

Finance

The responsibility for the financial working of a Station of this size is of no mean order. Apart from other much smaller (although significant) sources of income, the grant from the Agricultural

Research Council now exceeds £250,000. For the administration of this large income, as well as the various capital grants that have been made, the Committee would thank the efficient office staff, who have performed this task to the admiration of all. They would also draw attention to the many visits to the Station made by the Finance Chairman, who has now completed his first full year of office, to confer with the Director, the Secretary and staff, quite apart from attendance at Committee meetings.

The administration is not carried out without unforeseen difficulties. Thus the frost at the end of May made it necessary to apply to the Agricultural Research Council for an additional sum to cover its effects on the expected income from the experimental farm, and although—due to an early season—the income from farm produce actually exceeded £35,000, it was barely possible to keep down expenditure to nearly double that sum. Indeed, with a smaller carry-over of fruit in store than usual, another tight financial year must be expected in 1962/63.

Members may not realize how far ahead estimates of expenditure have to be made. Thus it was in December 1959 that Heads of Sections started to prepare the budget for 1960/61, while that for 1962/63 is being prepared before the sanctioned amount of the block grant for 1961/62 is known.

The East Malling Research Station Association

The large sums provided for staff salaries and general maintenance do not diminish by one iota the importance of the income from the Association ; some of the objects which it finances so admirably were detailed in last year's Report. Nevertheless, it was then evident that if these were to be maintained and the additional liability for the rent of the new land acquired by the Development Fund met, a reorganization of the Membership Scheme, to bring in a more realistic income, was overdue. It is now possible to assess to some degree how far the revisions (details of which were given last year) have been successful. By and large, the supporters of the Station responded unstintedly to the Chairman's appeal to them, and the income from subscriptions rose from an average of £4,300 to £7,105. Inevitably, some Members have resigned, either because—after a period of years—interest had waned, or because the higher subscription rates could not be entertained. It is a very considerable compensation —and a reassuring commentary on the lively interest in the Station of the present generation of fruit-growers and others—that during the year 150 new Members were enrolled. It is curious, however, that up to the end of September one-seventh of those that had been notified (sometimes several times) of the revised rates, had not replied but had continued to pay their old subscriptions by Banker's Order, as before. At that time, the total number of Members—including Life Members and those who had not replied—was 1,871.

Two items in the accounts that follow are worthy of note ; firstly, the contribution of £1,000 to be made towards the cost of erecting the new store for farm machinery, already alluded to (a building which is going to be much appreciated on Members' Days). Secondly, the Grange, which belongs to the Association and is one of the assets of the Station, since it provides a home for young members of staff and post-graduate students while they are here. While the cost of living to the tenants is not subsidized, occasionally there must be some large expenditure on the fabric of the building ; so, in this year, the Association contributed £663 towards very necessary structural repairs.

Members' Days

Current entomological research formed the major part of the programme on 23rd November. The control of codling moth and tortricid moths was discussed in relation to the need to avoid killing beneficial insects as far as possible—especially the predators of the fruit tree red spider mite. On this day, also, Mr. Preston told Members about the methods used for growing fruit in northern Italy, which he had seen during a study tour there.

The meeting on 22nd March brought to a close the series of seven similar meetings when the general keeping-quality of variously grown Cox's Orange Pippin was discussed. Samples of the fruit from gas (controlled atmosphere) storage were again on view, and the talks referred to the control of gloeosporium rots and to wastage by non-parasitic troubles.

On 9th May, following the Annual General Meeting, an informal programme of tours and talks was arranged. With top fruits, the chief subjects were rootstocks and pruning, and with soft fruits, problems with strawberries and black currants. There was also a general tour of a wide variety of field trials.

In the Annual Report for 1960, a growers' bulletin entitled 'The efficient fruit tree' showed how the plant physiologist examines how a tree works. On 25th May the same general subject was presented to Members in the plantations actually used for the experiments. A lively cartoon ciné-film, specially prepared for the occasion, helped to explain how the growth of different parts of a tree is measured.

The East Malling Research Station Association
Income And Expenditure Account

1st October 1960 to 30th September 1961

Expenditure	£ s. d.	Income	£ s. d.
Contribution to Research Costs ..	1,400 0 0	Subscriptions and Donations	7,105 11 10
Rent of Land and Cottages	2,350 16 8	Miscellaneous Receipts	1 6 0
Farm Pensioners	200 0 0	Interest on Loans, etc.	83 19 10
Studentship Fund	50 0 0		
Orchard Experience Overseas ..	50 0 0		
Evening Class Fees	20 17 6		
Staff Amenities	150 0 0		
Grange Structural Repairs	663 11 11		
General Expenses	890 16 3		
Surplus	1,414 15 4		
	£7,190 17 8		£7,190 17 8

East Malling Research Station Association
Balance Sheet

as at 30th September 1961

	£ s. d.		£ s. d.
Accumulated Members' Fund:		Freehold Property at cost:	
Balance at 30th September 1960 ..	10,704 3 2	Fircroft and Grange	8,792 13 7
Add surplus for the year	1,414 15 4	Studentship Endowment:	
—Farming Account	1,349 6 10	Investments at Market Value	15,511 7 7
	13,468 5 4	Cash at Bank and Income Tax due	1,716 14 5
Less deficit—Property Account ..	118 17 1		17,228 2 0
	13,349 8 3	Sundry Debtors and Interest	722 18 8
Studentship Endowment Fund ..	17,228 2 0	Cash at Bank	6,598 15 7
Farm Pensioners' Fund	677 7 0		
Sundry Creditors	1,087 12 7		
Contribution to Farm Machinery Store	1,000 0 0		
	£33,342 9 10		£33,342 9 10

Amos Memorial Lecture

The thirteenth Amos Memorial Lecture was delivered by Dr. J. T. Martin, of the Long Ashton Research Station. He described the structure and chemical composition of plant cuticle and discussed their effects on spraying problems. This year it was Wye College's turn to act as host, and the Swanley Hall was filled to capacity for the lecture. This was a fine tribute to the reputation of the speaker, as the 3rd November will long be remembered for widespread flooding all over Kent, which must have deterred many who would have liked to attend. The tour of the horticultural department, which preceded the lecture, was limited by the rain, but we congratulate the College staff for the interesting programme they arranged in spite of the weather. The full text of the lecture has already appeared (Annual Report 1960, p. 40).

Staff

One by one those who laid the foundations and the first bricks in the structure we now know as East Malling Research Station pass into retirement. At the end of this year we have had to say good-bye to Dr. A. M. Massee the founder, and for many years the head, of the Entomology Section, after forty years' service. Massee came here as a Ministry of Agriculture scholar in 1921 ; he played a leading part in developing the first really effective spray programme based on tar oil washes, and if any of the Malling-Merton woolly aphid resistant rootstocks finally become established as part and parcel of the horticultural industry, they will amply justify his early studies, which enabled each of some thousands of seedlings that were raised to be efficiently tested for resistance to the pest. His name will not soon be forgotten by the fruit-growing supporters of the Station. We would remind Members that Mrs. Massee was herself one of the first of our lady recorders. We wish them both every happiness in the small house they are building in East Malling.

It is some compensation to be able to report that another of our old-stagers, A. C. Painter, is still frequently to be seen about the Station, and has done noble work in the Record Office during the year.

With the ending of the year 1960/61, a further major Sectional reorganization is being made, consequent on the acceptance by Dr. A. E. Flood of the post of Senior Lecturer in the Department of Physical Sciences at Wye College. Although the Biochemistry Section, as such, will no longer appear in the Staff List, such parts of its work that (like so much of our research) are closely connected with that of others, will be continued, mainly in the Pathology and Physiology Sections. Dr. Flood leaves us after twelve years at East Malling, during which time he first worked with the late Dr. Bradfield and, since 1955, has continued his biochemical studies as Head of the Biochemistry Section.

Apart from these, there have been few changes to record in the senior staff.

Perhaps this is the place to congratulate Dr. R. V. Harris on the award of the Order of the Hop at the European Hop Growers' Convention in August—a most exclusive honour— and R. J. Garner, who is President of the Horticultural Education Association this year. These honours throw a gleam of light on some of the activities that have made these two workers very well known among particular sections of the community—Harris among hop growers and Garner among educationists.

We are sorry to have lost the services of Dr. E. S. J. Hatcher, who resigned in May. Hatcher first came to East Malling as an evacuee from the Imperial College in 1941. Since 1945 he has worked in collaboration with the Physiology Section, eventually joining its staff. His work with R. J. Garner on the rooting of cuttings will not be readily forgotten.

It is right to record here three tragedies that have depleted our ranks during 1961, although two of them did not occur until after the end of September.

In August the Physiology Section suffered a grievous loss through the untimely death of C. R. Hancock. He was with the Section for nearly twelve years, first as part of the staff of the Institute of Plant Physiology and, more recently, of the Research Station. His main studies involved natural growth substances and the detailed development of leaves and internodes. Our sympathy goes out to his colleagues in the loss of an excellent collaborator.

The name of E. C. Wills still appears at the head of the list of Assistants (Scientific) in the Fruit Nutrition Section, but it is with deep regret that we inform Members of his death in November 1961. Wills joined the staff of the old Biochemistry Section in December 1947, and we have long admired the courage with which he overcame his disabilities, joining in staff activities so far as he was able. His death after a long illness which—as we might have expected of him—was bravely borne, is greatly deplored.

Lastly, we have to report the tragic death in a road accident, in November 1961, of a very young member of staff who had only recently joined the Plant Pathology Section, Miss Christine Reader.

Other changes in the senior staff include the resignation of N. G. Smith from the Pomology Section in March 1961 and the appointment of D. H. Rees to the Statistics Section in October 1960. L. D. Hunter came from Glasgow to join the Plant Protective Chemistry Section in July 1961, and Miss E. D. Jacobs-Larkcom came to do biochemical work with the Plant Pathology Section in June. R. O. Sharples, a former Boots Scholar at Long Ashton, came in May to assist in the work on the storage behaviour of apples. The Bureau welcomed J. R. MacCormick in November 1960.

As usual, there has been the inevitable wastage in the ranks of the Assistants (Scientific), partly—we record with mixed feelings—occasioned by marriage. The Pomology Section has lost J. F. Naylor, Miss P. B. Topham, K. K. Yeabsley, Miss D. P. J. Wilson and Miss J. M. Rowcroft. R. J. Waller was a serious loss in the Record Office. Miss F. Lamb, after seven years in the Physiology Section, resigned on her marriage in July. Two members of the Plant Analysis team who were married a year ago, Mrs. G. M. Lindsell and Mrs. J. K. Newman, gave up their posts in April. And we must add that Miss Margaret Jenner, whose marriage in 1960 to D. J. Avery of the Physiology Section does not seem to have been recorded in these notes, also resigned in the autumn of 1961. Miss S. J. Cogger left the Pathology Section in October 1960 and was followed eleven months later by Miss G. Bircham. D. W. Jenner (Entomology) went to the Shell Woodstock Research Institute in November 1960 and took with him as his wife the former Miss D. I. Wells. Miss B. F. Ranft resigned from the same section in July.

In face of growing competition in the neighbourhood, all of these have been replaced, and the names of those who have come will be found in the Staff List. But we would record that many of our Assistants (Scientific) now have to come here daily from considerable distances—by car, moped, 'bus and train—a rather regrettable symptom of the growth of the commercial enterprises surrounding us.

This year the Farm Staff have a clean sheet, with no changes, and we can only congratulate Mr. Villiers on keeping together the team from whom we expect and obtain so much.

In the Office there is a considerable turnover, as we must expect, since the clerical staff are affected by the same factors as influence Assistants (Scientific). Among the senior office staff, however, many from among the staff and the Committees will miss Mrs. R. Cook, personal secretary to the Director until August 1961, who has now accompanied her husband to Reading, where he has taken up a new post. They will likewise wish her successor, Miss D. Crump, every good fortune.

If we appear sometimes to take for granted the continued functioning of the various internal Committees throughout the years, it is not intentional and we are truly grateful to all those who undertake work on them. This year we would like to show our appreciation of those who attend daily to the inner man (or woman, as the case may be) and extend our thanks to the housekeeper and kitchen staff of the canteen who, apart from anything else, seem to have ensured that the tasks of the Canteen Advisory Committee have been light.

Organized Visits

It proved impossible to organize more than two visits this summer. The first, on 29th August, was to the experimental station of I.C.I. at Fernhurst, where an excellently planned day was enjoyed by everyone. Highlights of the visit were the experiments with a new herbicide and new aphicide. The party was impressed by the thorough testing that preceded the introduction of any new chemical.

The second visit, on 19th September, was to fruit orchards in the Rye area. The morning was spent on the holding of Walter Merricks and Sons at Icklesham, where Mr. Dick Merricks and his Manager, Mr. J. Austen, showed us the extensive fruit plantations. A particular point of interest was bulk bins for apple harvesting. Mr. J. Roberts of Iden received our party in the afternoon, and showed a variety of specialized equipment to ease the work of the grower. We wish to record our sincere thanks to those who received us so kindly and hospitably on these visits.

Social and Athletic Activities

Members of the Association who examine the year's accounts on page xvi will note a small sum which is donated each year towards staff amenities. The Staff Representative always thanks the Committee especially for this grant, since it not only finances such annual events as the Christmas and Children's parties, but enables capital grants to be made with which to start social and athletic clubs and to re-equip them from time to time with such larger items as they cannot afford themselves. Most of our clubs, however, are now standing on their own feet and requests for assistance have been on a very modest scale in recent years. The new piano at Bradbourne, which the Music Club have made financial arrangements to acquire—assisted by the Amenities Fund in only quite a small way—is an example of what the staff do to help themselves.

In his report on staff activities during the year, C. H. W. Slater, the Social Secretary, shows that nearly all of the clubs had busy seasons—the athletic clubs with lots of practice games and a full programme of matches. We have not ventured to ask how many of these matches were won or lost, and he—perhaps tactfully—does not tell us. But that does not matter ; the staff play games for fun. Matches against the Association continue to be a highlight in the programmes of the hockey, cricket and tennis clubs, and it is whispered that the Members go to considerable trouble to field sides capable of beating the Research Station. Good luck to them! But they don't always succeed.

We are glad to note that the Tennis Club has played frequently on the recently re-surfaced court and that the Music Club has made good use of the new piano they worked so hard to acquire. Also, congratulations to members of the Garden Club, who put up such a marvellous show in September, despite the dry summer which made most gardens look like a desert.

This year the staff have broken out in a fresh place, with the publication of a magazine called ' Agag ', which has achieved two editions.

Memories of the 1960 Christmas party are beginning to fade, though hordes of young ' ladies ' of revolting aspect, who must have tried Miss Seymour's phenomenal patience to the full, are memorable. Those who organize these parties have been a little worried because the dancing with which the party has always ended has not been well patronized ; perhaps it is because so many married couples must go home at 10 o'clock to relieve the baby-sitter, while the older generation tend to think of their beds at about the same time. There were signs of improvement in 1961, though the number of dancers on the first night was still small. It would be nice to have a hall large enough to accommodate the whole staff and their wives on one night ; but that is a pipedream (and we have said it before, anyhow!).

We have left no space to mention those perennial events, the Children's Party and the Farm Harvest Supper, and can only add that both passed off hilariously, as usual.

Postgraduate Students

It seems no time since the institution of the Blackman Research Studentships, and it therefore came as a shock to learn that the first student—M. G. Morris (Entomology)—would be completing his term in the autumn of 1961 and leaving to take up a post with the Nature Conservancy. Three

other Blackman and Boots scholars were in residence during the year. A further award was offered, but was not taken up.

One member of staff, M. Allen of the Fruit Nutrition Section, and one whole time postgraduate student in Plant Pathology, L. D. Wolfswinkel (of South Africa), were awarded Ph.D. degrees by the University of London. At the end of September 1961 there were nine registrations for higher degrees ; five members of staff and four postgraduate students.

The year saw the institution of a special meeting to enable postgraduate students to give accounts of their work to a gathering of permanent members of staff. Messrs. Morris and Wolfswinkel gave an excellent start to these sessions, and a lively discussion ensued.

The work of the Station has been enriched by the sojourn among us of Miss J. M. Bain from Australia, who spent six months attached to our fruit storage investigations team, and Dr. M. F. Welsh from Canada, who came in May for a year's work with the Plant Pathology Section.

The Statistics Section has had three short-term students—L. M. Fernie from Tanganyika, R. L. Constable from Aberdeen and R. H. Wimble (prior to taking up a lectureship at Wye College). Yong Soo Rhee, from Korea, spent two months with Pomology and Fruit Nutrition.

A course of lectures in Statistics, followed by practical work, was arranged during the autumn of 1960 especially for postgraduate students in residence here at the time. This certainly widens the experience gained by students during their time here, and it is hoped to repeat it as circumstances permit.

Temporary Recorders

Conditions in 1961 are very different from those twelve years ago, when the first temporary recorders were enrolled. To-day, a wide choice of vacation employment is open to the university student. Perhaps this is the main reason why, despite efforts to achieve a still wider ' scatter ' of notices to heads of university departments, far fewer applications were received than usual. In the event, fifteen students were accepted for periods of a month from seven universities—six coming from colleges in the University of London. The quality of those who came, however, proved very high. This being so, the assistance in the field at peak periods in the summer was greatly valued.

Plantation Assistants

These assistants come here, usually with considerable practical experience, for a period of two years ; they spend their time working on the experimental farm, assisting the research staff in the wide range of farm operations necessary to grow plants for field experiments. In sixteen years they have firmly established themselves as part of the research team. In part return for their services they receive a course of lectures from members of staff and experts in other fields, including in 1961 such well-known personalities as S. R. Dixon, C. L. Newitt, E. S. Devine and F. A. Roach.

The all-male team of a year ago has been leavened by the inclusion of two girls, and it is with pleasure we see also the name of M. Mika—the second Polish graduate to think it worth while to gain experience as a Plantation Assistant at East Malling.

The winner of this year's medal awarded by the Worshipful Company of Fruiterers was John Ballard, and we understand that he made his mark subsequently when he attended a dinner of the Court to receive his prize. He is now adding to his experience of commercial horticulture.

Staff Discussions

The whole staff gathered at Bradbourne on four occasions to discuss the horticultural problems of the day. The first of these was devoted to bringing everyone up to date on the subject of bacterial canker, and it must be confessed that most of those present had to accept what they were told by the pathologists without demur. The next two, however, produced plenty of argument—soil in relation to fruit growing and the effects of leaf injury being subjects on which many are prepared to lay down the law, whether they have any experimental evidence or not. Surprisingly, however, the last subject of debate —Fact and Fiction in Fruit Growing—did not provoke as much discussion as might have been expected. Perhaps some are nervous of averring whether the fruit-growing practices of to-day are the outcome of scientific proof or are merely based on tradition ; though when it is realized that some comparatively recent discoveries (of which the present generation is so proud) were well known among gardeners many years ago, the authenticity of tradition ought not to be lightly questioned.

The special discussion allotted to postgraduate students in their final year has already been men-

tioned. Specialists in appropriate sections got together on three other occasions to discuss aspects of their researches in the more rarified atmosphere of the Discussion Room.

East Malling Abroad

This section of the Report continues to grow, as visits of staff to institutions abroad become more widespread—thanks to the generosity of the Agricultural Research Council and other Institutes, and last but by no means least, the resources made available by our own Association.

Starting at the beginning of 1961, the Director was in East Africa for three weeks on behalf of the Empire Cotton Growing Corporation ; while at the end of January G. W. F. Sewell left for California with a grant from the Kellog Foundation, concluding a study period with visits to many Stations in North America and returning in early August. Starting at the beginning of the next month, B. F. Self was given leave to spend three months at Wädenswil, at the invitation of Dr. Kobel.

During the spring and early summer there were frequent visits to the continent of Europe ; R. M. Fulford took part in a colloquium at Gembloux and afterwards accompanied one of the Blackman students, D. S. Skene, on a tour of Holland ; Miss B. G. Mosse attended a course on electron-microscopy at Zurich ; Miss Modlibowska, accompanied by C. H. W. Slater, studied frost damage in France and West Germany ; R. L. Knight attended a Eucarpia congress at Wageningen ; R. T. Burchill was at Ghent in May, after which he visited laboratories working on storage rots ; in the same month, G. H. L. Dicker, J. E. Crosse and M. H. Moore went with a party of the Kent N.F.U. Fruit Committee to learn about pest and disease warning services in the Low Countries ; in June R. I. C. Holloway went to study the use of herbicides on fruit crops, while R. J. Garner accompanied a member of staff of the Rubber Research Institute of Malaya to see mist installations—both in north-eastern Europe. In July Miss E. Keep was at the Plant Breeding Station at Lemberge and R. S. Pitcher was at Ghent for the symposium on nematology.

In August R. C. Cropley went to the U.S.A. for a conference on apple tree disorders, and took the opportunity to visit research centres in the east. In September R. C. Muir was at Wageningen, at the invitation of the Institute of Phytopathological Research (I.P.O.).

We are not sure whether or not Eire comes into the category of countries abroad, anyhow—also in September—D. W. P. Greenham was at a meeting of soil scientists in Dublin.

Miss E. Collyer spent the second year of her National Research Fellowship in New Zealand, working on the natural enemies of the fruit tree red spider mite ; as we write, however, we can report that she has now returned safely to this country.

It is evident that the research staff have found their way to many countries during 1961, and this affords much gratification to the Committee. Space does not permit the inclusion of the long list of visits made within the United Kingdom ; nevertheless, Members will be left in no doubt as to the ramifications of East Malling beyond the confines of this small Kentish village, and the part that is being taken in horticultural research throughout the world.

Collaboration

The search for information is pursued in many parts of the world, and it does not matter very much where the investigators come from—be it the United Kingdom, the United States, Australia or elsewhere—as long as the right experts get together with the intention of finding the right answer as quickly as possible. A glance at the section of this Report dealing with visits overseas will leave no doubt that the staff at East Malling are travelling far and wide to meet their opposite numbers—a process that is benignly encouraged by those who make it financially possible for them to go. Such visits are, of course, primarily intended to widen experience and acquire knowledge, but they frequently result in collaboration in one of its many forms.

Likewise, within the United Kingdom, there are few institutions engaged in biological research whose staff are not collaborating with the Station in some way ; few Advisory Officers in the N.A.A.S. or L.E.A. who do not help the staff at some time or other by finding suitable places where experiments in this country can be done ; while many fruit growers give free access to their farms and every encouragement to carry out experiments thereon as needed.

Perhaps we are a little inclined to take this form of collaboration—particularly on the part of our near neighbours—for granted. If we have done so in the past, it does not mean that their help is appreciated any the less.

Few members of staff here are experts on machinery, but this aspect of horticultural research grows more important each year, and it is a great advantage to have the advice and active help of the staff of the National Institute of Agricultural Engineering at Silsoe. Recently they have been helping to

develop a machine for applying fertilizers uniformly ; while in the autumn of 1961 it was fascinating to watch the machine evolved at Silsoe inserting the P.V.C. foil that is to take the place of guard trees in the new irrigation trial—alluded to last year and again now in the Farm Report (see p. 3).

The work here has long been associated with cover crops in fruit orchards, and now we must acknowledge the help of the Grassland Research Station and the Plant Breeding Institute at Cambridge in supplying seed for a trial of Tall Fescues with a view to their use in orchard swards.

It is a pleasure to note the continuation of the scheme for interchange of Sectional visits with Long Ashton, the entomologists spending three days there in April.

The course of instruction in statistics at Wye College was followed in the autumn 1961 by lectures by S. C. Pearce and D. A. Holland to the botany students at King's College, London. Miss Beakbane and D. W. P. Greenham also lectured at Wye.

Space only remains to mention a few new subjects of collaboration in which others have helped this year—e.g. anatomy in relation to the rooting of softwood cuttings in mist ; the study of fruit skins by electron microscopy ; pollination trials with plums ; new rootstock and tree spacing trials and the incidence of collar rot in relation to high and low working of fruit trees ; the effect on the flavour of strawberries from plants treated with aldrin.

It is evident that as the years roll by the collaboration between those engaged in horticultural research grows wider and wider. We are proud to be members of a world-wide team engaged in the task.

Scientific Societies and Conferences

The staff have attended many of the regular meetings of scientific societies and joined in the discussions. A. H. M. Kirby described glasshouse studies on the effects of chemicals on powdery mildews at the December meeting of the Association of Applied Biology. He also gave the opening talk on current usage and recent developments in the fungicide symposium organized by the Pesticides Group of the Society of Chemical Industry in March. In January, R. S. Pitcher spoke on nematode vectors of virus to the A.A.B.

Barbara Mosse spoke on the establishment of mycorrhiza under aseptic conditions at the meeting of the Society of Experimental Botany in January. With R. Cooper and R. M. Jackson she addressed the Society of General Microbiology in April on the nitrogen balance between soil micro-organisms and seedlings. She also demonstrated the germination of *Endogone* spores and the synthesis of vesicular-arbuscular mycorrhiza at the Institute of Biology in June.

At the June meeting of the A.A.B., R. Cropley described the viruses isolated from cherry trees with rasp leaf and leaf roll diseases. D. H. Maggs contributed a paper on the pattern of growth in apple trees at the Aberystwyth meeting of the S.E.B. in July. R. I. C. Holloway gave a short paper on the use of simazine and monuron on top and soft fruit at the British Weed Control Conference in November.

In September, J. M. Thresh attended the Cocoa and Confectionery Alliance Conference, and J. T. Legg the A.R.C. Virus Symposium in Cambridge.

At the invitation of the N.A.A.S. Plant Pathologists, D. A. Holland addressed their open conference on experiments with fruit crops.

Information Services

Many different methods are used to give the results of our research to all those who are interested. For fruit growers the National Agricultural Advisory Service continues to be the main channel of information, and special efforts are made to keep the Advisory Officers up to date. We invite them to attend dress rehearsals of Members' Days and also arrange an annual two-day visit and other short courses for them. The research staff—especially in the Scientific Liaison Section—reply to many letters and 'phone calls from fruit growers, and can often inform the grower of the additional help he can obtain from his local Advisory Officer. Enquiries by post totalled over 1,200 during the past year. Arising from these, twenty-two visits were made to particular fruit farms.

The staff have been busy talking to N.F.U. branches, discussion groups, gardening societies, etc., in most of the fruit-growing areas. Of the thirty-eight lectures given, thirteen were in Kent and the rest were distributed amongst no less than fourteen other counties in the southern half of England. On several occasions the lectures were supplemented by field demonstrations. Members of staff helped, as usual, with judging at the chief commercial and amateur fruit shows. G. H. L. Dicker and A. P. Preston judged in the Paddock Wood orchard competition. We were to have helped again

with the similar competition in West Sussex, but it was cancelled after the damaging frost at the end of May.

During the spring and early summer the Maidstone Branch of the N.F.U. were notified of the occurrence of Mills' periods at the Station. From time to time during the season special notes were sent to Members and to the trade press calling attention to the best treatments for pests or diseases that were causing concern. Members also received a summary of the observations made during 1960 on the MM rootstock demonstration plots, and detailed reports of each of the four Members' Days and the Amos Memorial Lecture.

The exhibit at the Chelsea Flower Show explained some of the tests made on new insecticides to determine their toxicity to pests and beneficial insects, and any toxic residues that remain at harvest time. At the County Show at Maidstone the exhibit showed the control of some strawberry diseases, and at the Marden and Canterbury Shows the control of apple scab. We helped the N.A.A.S. and the Maidstone Young Farmers' Club with information and material for their exhibits at the County Show. This is probably also the place to mention that the B.B.C. Midland TV sought assistance in making a film of hop growing, and that a visit of some members of the Kent Y.F.C. was recorded for the Colonial Office, to form part of a film on the activities of the Young Farmers for sending overseas.

In June, the Royal Agricultural Society of England arranged a demonstration of fruit tree spraying machines at Sittingbourne. M. H. Moore and H. B. S. Montgomery served on the organizing committee, and our photographer undertook the considerable task of making pictures of leaves showing the spray deposits achieved by each of the different machines.

With the help of A. C. Painter, specimens of fruit from the Station were regularly displayed on the Fruit Group table at the R.H.S. fortnightly shows. An exhibit of late apples in November 1961 received a Silver Lindley Medal.

Visitors

Although one member of the Scientific Liaison Section spent three months on a study visit to Switzerland, and a back injury deprived the section of the help of another for seven weeks, rather more than the usual number of visitors were entertained. This was possible because the Section was at full strength during the summer months, when most of the visitors come. We enjoy meeting those who are visiting the Station for the first time, and are glad that so many old friends call again. These visits can contribute much to the exchange of information between workers in all parts of the world.

We cannot attempt to list all those individuals and parties who visited us. We are, however, particularly grateful to the Board of Studies in Botany of London University, who arranged one of their regular meetings at the Station so that they could see something of the botanical research in progress. The ' Special Botany ' students of London University included the Station in their programme of Inter-collegiate visits. It is some years now since the Worshipful Company of Fruiterers honoured us with a visit, but it was a pleasure to welcome the Fruit Culture Council of this Company ; we hope that their visit is a prelude to more frequent visits by the Company itself.

From overseas we had a party of senior French physiologists, under Professor Chouard, advanced students from Wageningen under Professor Oort, the Swedish Pomological Society, and the Directors and Senior Officers of Overseas Departments of Agriculture.

In the spring, the H.E.A. organized a Craftsmanship Course at the Station, when all aspects of the craft of propagating fruit trees were demonstrated by Messrs. Garner and Byford and their helpers.

Distribution of Experimental Material

It is not easy to write in this Report of the year in the experimental nurseries, since it covers both the harvesting and despatching season that followed the summer of 1960 and the growing season of 1961, the compilation of the Distribution List of July 1961 and the receipt of most of the orders from that list.

We remarked a year ago on the wet season of 1960, but did not at the time anticipate the continuous wet winter that followed it, which will not readily be forgotten by any member of the nursery staff. Evidently the wet summer had favoured the growth and rooting on the stoolbeds of some rootstocks, but that was not so for others. Moreover, the experiences of growers who had planted trees on MM.104 on poorly drained land seriously affected the demand for that previously very promising rootstock—though this was not apparent until the orders were received in the autumn of 1961.

In the fruit-tree nursery, having learnt the hazards of planting apples on land previously occupied by apple stoolbeds, the rows were reorientated so that successive plantings were not of the same species.

The result was an excellent nursery of maiden trees in the autumn of 1960. But the continuous winter rains held everything up ; not only was the harvesting and despatch of material exceptionally difficult but some of the experimental plantings at home were not made until very late in the season, after trees had been heeled-in for several months. It was surprising how well these have come through the very dry spring and summer weather of 1961.

Among the rootstocks offered in the Distribution List for 1961, three clones of Quince A that had been tested and found free of nine viruses were offered and eagerly taken up. This is not the final selection of Quince A, but considerably more of these layers were available than were needed for research and the selections are probably more reliable than the old untested clone, so it was decided to offer them to Members at once. All the other rootstocks included had been offered in previous years; in this year there were very heavy demands for the new semi-dwarfing apple rootstock M.26 and the Malling-Merton woolly aphid resistant rootstocks MM.111 and MM.106.

In the 1960 Distribution List, no less than fifty varieties of virus-tested apple, pear, cherry and plum had been offered as mother trees. In the subsequent winter, nearly 600 trees were actually supplied—of which about one-quarter had been worked especially at Members' requests. Only two new selections were added in July 1961—Egremont Russet apple and Roundel cherry (the second being not entirely free, but of minimal virus content)—but in the spring of 1962 we are prepared to graft trees, on request, of a wide range of varieties that have been passed by the pathologists since 1953.

The supply of plants between research institutions throughout the world is now a commonplace in horticultural research. This Station certainly does its share, and we like to think that our contributions are of value—notably to newly-formed institutions. One such consignment—sent to India—contained 43 different kinds of rootstock, graftwood of 40 virus-tested scion varieties and some strawberries and loganberries! The collection, accurate labelling, packing and despatch (with the appropriate certificates) is no light task but one which, however arduous it may seem at the time, cements the association with other research workers all over the world and often pays unexpected dividends. As the Plant Index book witnesses, we are receiving annually large numbers of plants in return.

Station's Publications

Almost exactly half of the 62 research papers published during the year have appeared in the *Annual Report* or in the *Journal of Horticultural Science*. The former is already in the hands of all Members and a brief summary of the content of the quarterly-published Journal appears on the inside back cover each year. In the current Volume 37 (1962) Members will be interested in the second report on variability following the clearing of established trees and a comprehensive account of the results of storage experiments with Cox's Orange Pippin. Various improvements have been made in the presentation of this Volume. Other research papers during 1961 have appeared in journals such as the Annals of Applied Biology, Annals of Botany, and similar specialist scientific journals.

Research results of immediate practical interest to fruit growers were presented in sixteen articles, five of which were in the Annual Report for 1960 and the rest in trade papers and similar journals in this country and in France and Belgium. There are complete lists in Part II of this Report.

The Library

The library, which is housed at Bradbourne, with an ancillary reading room at the Research Laboratories, is shared by the Station and the Commonwealth Bureau of Horticulture and Plantation Crops ; the Chairman of the Station Library Committee is also the Director of the Bureau. Modestly, in his report, he does not mention this, but we do so now to remind Members of the advantages they enjoy as a result.

The importance of a library may be measured by the value of its holdings and by the use that is made of those holdings. On both counts the library at East Malling must rank very high.

The expansion in agricultural research in many parts of the world has inevitably resulted in the publication of more literature. Experience suggests that at present the rate of expansion is somewhere in the region of ten per cent per annum. In the East Malling library every effort has been made to keep pace with the production of new publications in so far as they are likely to prove of real value to the staff of the Research Station. Thus, it is not surprising to record that nearly a thousand journals and annual reports are now regularly received, with double that number of books, bulletins, etc.

The continued extensive use being made of the library also gives cause for satisfaction. Within the Research Station over 4,000 items were provided on loan ; no less than a quarter of which were journal parts supplied under the automatic circulation system. In addition, many items were supplied

and borrowed under the inter-library lending arrangements and, with the aid of the Bureau, photostat copies of articles supplied to persons in other research organizations. Finally, considerable use was made of the library by visitors—among them several from overseas.

The expansion in library holdings and activities has not been achieved without certain administrative difficulties. To maintain the loans service mentioned above creates for the librarian a mass of routine clerical work, which leaves him little time to devote to enquiries and the other duties that are commonly undertaken by qualified librarians. Similarly, his Bureau assistant is fully occupied in the preparation of accessions lists and in handling extensive inter-Bureau loans. In the circumstances, it is pleasant to be able to record that the library continues to maintain its high standards without any sign of fuss or friction.

RESEARCH REPORT

Part 1

THE EXPERIMENTAL FARM

After the tremendous apple crop in 1960, lighter crops were expected in 1961, but what could not be foreseen was the latest spring frost since the Station was founded, followed by a summer drought. All these factors combined to make 1961 a year of light crops of some of the more important apple varieties at East Malling. However, crops of soft fruit were good and of plums moderate, so that on the whole the year was satisfactory. The exceedingly wet autumn and winter seriously delayed the lifting of nursery material and the planting of experimental plots, but the weather became unusually warm in February. This caused all fruit plants to start growth very rapidly and the blossoming season was the earliest for some years. On 17th March the temperature reached 75° F and the weather continued favourable throughout April and early May providing good conditions for pollination.

On 27th May a sharp frost caused widespread damage for, although the air temperature at 4 ft only fell to 30° F, the forward condition of the trees rendered them vulnerable where the fruit was exposed to the sky. Apples, pears and plums suffered most but some soft fruit was also affected. Damage was largely confined to the developing fruitlets but sometimes leaves and young shoots were also killed. An unusual feature was the number of fruits slightly damaged without showing external symptoms ; such fruits were not always shed during subsequent months, so that that the keeping quality of some of the picked crop was suspect.

From May until the end of the season the weather was hot and dry and trees on the lighter soils on Larkfield plantation wilted badly in early August and there was much premature defoliation on some apple varieties both there and elsewhere. The season was about a fortnight early throughout ; the first Myrobolan plum blossoms opened on 24th February and the first Early Rivers cherries were marketed on 12th June. Apple packing was all finished early in October.

The remaining 82¼ acres of the Trust Land, all pasture, came into the possession of the Station on 30th June. It is planned to add 25 acres of this to the part of the farm under experiment during the five years 1962-66, resting a corresponding area of the main farm that has already carried fruit experiments. This area will be on Palmers Rough and Calves Leys, parts of which are being planted in autumn 1961. The remainder of the Trust Land will be under arable crops for several years to come.

Experimental orchards

Top fruits

Apples.—In spite of the lighter blossoming and adverse weather, a total of 199 tons of all varieties was harvested. This compares with 350 tons in 1960 and a 10-year crop average of 257 tons. The lightest cropping variety was Bramley's Seedling which bore little blossom and yielded only 6 tons of fruit as compared with 34 tons from a similar number of trees in 1960. Our other main culinary variety, Lane's Prince Albert, had carried an average crop in 1960 and, after the May frost, it was decided not to thin the fruits ; in consequence this variety did exceptionally well and yielded 25½ tons from just over 3 acres. One 42-year-old tree of Lane's on M.IX bore 220 lb of fruit, thus refuting the original forecast that this combination might be short-lived.

The crop of Worcester Pearmain was again very satisfactory and, except on the lighter soil, fruit size and quality was excellent. Trees of this variety in the pruning trial on Church Fields West (C12) now 16 years old averaged almost 4 bushels per tree, one of their heaviest crops so far. The crop of Cox's Orange Pippin was light, only 30 tons as against 86 in 1960. With this variety, also, the fruit was mostly of good size but the quality was marred by much stalk end cracking and russeting. Cox suffered badly from drought and the fruit from trees on the light soil on Larkfield plantation which

earlier looked very promising was almost unsaleable. Jonathan trees on the other hand withstood the drought well and gave a good crop of very handsome fruit. Trees of Laxton's Fortune on Church Fields West again bore a useful crop and now seem to be cropping more regularly; those of Laxton's Superb, however, were almost completely ' off ' and the crop was under a third of that in 1960. The yields of Ellison's Orange and Lord Lambourne were satisfactory.

Pears.—Following the heavy crop in 1960, this was not generally a very promising year for pears and the crop was probably further reduced by frost damage, much remaining fruit being seedless. Only 10 tons were harvested as compared with 24 in the previous year. Conference blossomed freely but many of the young fruitlets dropped, and those that remained were small because of the drought. In the rootstock trial (E36) 40-year-old trees only gave 79 lb per tree, less than half the average crop since the plantation was thinned in 1956-57. Trees of Williams' Bon Chrétien, on the other hand, did not produce much bloom but what there was set well and the fruitlets did not drop excessively, giving large fruit but only about a 30% crop. The young pears planted in Merryweather in 1957 and 1958 grew well in spite of the drought and should soon begin to produce a worth-while amount of fruit. Six-year-old unpruned Doyenné du Comice are now over 10 ft high, but the highest crop so far from any one tree is only 27 lb. On the Trust Land there was little blossom on either Conference or Williams' and a very disappointing crop.

Cherries.—The only cherries now remaining on the Station are 32 trees of mixed varieties planted in 1951 on Park Farm (P5), $1\frac{1}{4}$ acres of Merton Heart, Merton Bigarreau, Napoleon and Early Rivers on Church Fields (C5), and the young orchard in Newgates (N1 and N2) planted in 1953 and 1956. This miscellaneous collection yielded a total of 345 halves in 1961. Most of the fruit came from P5 where 10-year-old trees of Merton Bigarreau averaged 150 lb per tree. On Newgates field 6-year-old trees yielded up to 40 lb per tree. The weather at picking time was good and all the fruit was of good quality, though the earlier varieties suffered badly from bird damage.

Plums.—Unlike apples and pears, 1960 was an ' off ' year for plums, and the prospects for 1961 were good ; despite frost damage, these were realized and 42 tons of all varieties were picked, compared with 38 tons in 1959, the increase being largely due to the coming into cropping of young plantations. In the rootstock trials 9-year-old trees of Cambridge Gage and Rivers Early on Egham Field (E27) yielded 35 lb and 45 lb per tree respectively, while on Newgates 5-year-old trees of Victoria averaged 40 lb per tree, and Yellow Pershore, Anna Spath and Severn Cross 25 lb. Anna Spath is a late blue dessert plum with a good flavour, and the fruit travels well. This variety may well prove useful, coming as it does after most other dessert plums. Several 12-year-old trees of Marjorie's Seedling on Park Farm (P9) yielded over 200 lb of fruit and Cambridge Gage up to 80 lb.

Older trees of Victoria, Cambridge Gage, Marjorie's Seedling and Ontario all yielded well. The fruits of Victoria were mostly thinned to 2 in. apart and reached a satisfactory size in spite of the drought. By keeping the fruit in cold store at 34° F for 14 days, greatly enhanced prices were obtained; there was very little wastage.

The plums on the Trust Land also cropped well ; Yellow Egg bore 5 tons, Giant Prune 9, Wyedale $5\frac{3}{4}$, and Merryweather Damson 2, giving a total of $21\frac{3}{4}$ tons from the $3\frac{1}{2}$ acres. Wyedale, a late cooking plum maturing in October, sold particularly well at £50 per ton. The Merryweather Damsons on the other hand are not popular in the London markets and seldom make much money.

Soft fruits

The outstanding feature of this year's soft fruit season was the excellent crop of black currants. In spite of some ' running off ' caused possibly by the spring frost all varieties yielded well. The 7-year-old Amos Black and Baldwin on the irrigation and nitrogen trial on Egham Field (E27) were outstanding. Here the total crop from $\frac{3}{4}$ acres was 77 cwt (4·8 tons per acre) made up of $53\frac{1}{2}$ cwt from 432 bushes of Amos Black and $23\frac{1}{2}$ cwt from 240 bushes of Baldwin. The planting distance is 8×5 ft and treatments have resulted in very large bushes which meet in the rows, but picking was not unduly difficult and fruit size is so far well maintained. The main black currant plantation on Newgates Field (N4), which is the same age, consists of approximately $\frac{1}{2}$ acre each of Mendip Cross, Wellington XXX and Westwick Choice in pruning, weed killer, and frost prevention trials also spaced 8×5 ft. The Mendip Cross yielded at the rate of 2·3 tons, Wellington XXX at 4·2, and Westwick Choice at 5·6 tons per acre. The yield of the latter would probably have been even higher had not heavy applications of weedkiller damaged some of the bushes. This plantation is not irrigated but receives a dung mulch along the rows each year, and here too the bushes almost fill the ground. This makes it difficult to apply the dung and to remove fruit and prunings, but the dense growth shades out most of the weeds and greatly reduces the need for hoeing and cultivation.

The raspberry crop was also a good one, the one acre block of Malling Exploit in Newgates (N4) planted in 1956 cropped at the rate of almost 6 tons per acre, its best performance so far. Most of the

fruit was marketed before the effects of the drought became serious. The adjacent acre of the late variety Norfolk Giant, however, suffered badly from lack of rain and many of the fruits failed to mature. The crop, which was also reduced by some of the weedkiller treatments, was at the rate of 4 tons per acre. This plantation also receives a dung mulch each winter.

The strawberry acreage was again small and attacks of verticillium wilt were widespread ; most of the new plantings are of Cambridge Favourite, Redgauntlet and Cambridge Rearguard which, being partially resistant to this disease, should prove more satisfactory. Although the frost killed many of the early blooms, the almost complete absence of botrytis largely compensated for this.

Fruit marketing

The May frost distorted some fruitlets of all varieties of apples but the effect on quality was much less serious than that of the hail in the last three years. Some apple and plum thinning had been done before 28th May but some of this was probably unnecessary and may have even reduced the crop on trees on the lower parts of the farm. When the evident frost damage could be assessed, thinning was continued on other plantations and, in view of the dry weather which followed, proved well worth while.

Fruit colour was generally good, Worcester Pearmain being the best both for colour and size for some time ; despite the abundant sunshine and two pre-harvest drop sprays, Laxton's Fortune, however, did not colour very well.

To reduce labour costs all apples are now marketed in 30 lb cardboard cases, the ' Fancy ' grade with Hartman leaves between the layers and ' Choice ' fruit jumble packed. As far as can be judged this form of presentation is quite acceptable in the London markets. The saving in labour is very considerable—eight women handled more apples than did twelve wrapping into B.S.A. boxes last year. The only difficulty is that the varying density of the many varieties grown at the Research Station means frequent adjustment to the grader to ensure that each case contains a full 30 lb. As prices were good, all Worcesters were marketed at picking time and our larger cold stores were therefore available for other sorts ; one was filled with Lane's Prince Albert and Bramley's Seedling, and the other two with Ellison's Orange, Laxton's Superb, Jonathan, and Barnack Beauty, all of which are likely to be marketed before Christmas, because of the possibility of breakdown due to internal frost damage in some varieties. The four smaller rooms are used to store the Cox's Orange Pippin donated by growers for storage experiments. Almost all of our own crop was required to fill up these chambers.

The bulk of the soft fruit crop was again sold for processing, but strawberries, loganberries and blackberries were sold in one pound and half pound punnets as in previous years. Limited quantities of loganberries sell well as fresh fruit, but there is little interest from the canners. Raspberry prices remained at the 1960 level, some £40 per ton less than 1959, consequently only heavy crops are now profitable because of the high picking costs. All cherries and dessert plums were graded and the best sold in 12 lb trays.

Fresh planting and grubbing

The first 25 acres of the Trust Land became available for experiments in the autumn of 1961, thus enabling several major field experiments to be accommodated. Just over 3 acres of Bramley's Seedling with Howgate Wonder as pollinator are being planted in Calves Leys on a range of rootstocks. These trees will be planted diagonally at 25 ft at first and will be thinned to 35 ft when necessary. On Calves Leys, 3½ acres are also being planted with rootstocks for the Physiology Section. These stocks (M.26 and MM.104) will be worked *in situ* with Cox, Egremont Russet and Worcester Pearmain and the resulting trees used in experiments to assess the effects of different pruning systems on growth and cropping. Nearby on Palmers Rough, 4½ acres are to be planted with the same varieties all on MM.104 for use by the Fruit Nutrition Section. These trees will be used to assess the effects of differing irrigation and manurial treatments.

On the older part of the experimental farm, Ditton Fields is being used in 1961-62 to accommodate a variety of short-term laboratory trials, including closely spaced plums and cherries for pathology experiments, and other intensive work on apples, black currants and strawberries. Other short-term laboratory trials are being accommodated on Egham Field (E28,/29) and Kiln Field (K8) and a small area of black currants has been planted adjoining P5 for frost protection studies. On Newgates Field (N4) two further strawberry experiments have been placed and ¼ acre of closely spaced cherries is being added to the insecticide and fungicide testing area on P10 and P12.

Now that the younger plum plantations are coming into bearing, it has been decided to grub the 24-year-old dessert plum variety collection in Deadman Field (D2). In Egham Field the remainder of the 41-year-old Cox rootstock trial (E32) is also to be cleared, as will also be the remainder of the cherry double working trial in the same field (E28). In Newgates (N3) two rows of apple and pear cordons have been removed from the area in which intensive trials have been placed during the last

10 years or so, as has a ½ acre plot of black currants used in a pathology trial in the same field (N4), which has become badly infested with big bud mite. To make room for a further expansion of the greenhouse area, four rows of 43-year-old Bramley's Seedling, grown without any fertilizer for the first 10 years and thereafter used for manurial trials are also to be grubbed. Many Members will be sorry to see these old trees go but it is essential to keep the greenhouse area as compact as possible.

Routine spray programme

Continuing the practice of recent years, winter-washing was largely confined to nursery material and young experimental plots, 5% tar oil being used as necessary. The only DNC applied was on two small areas where apple mildew has been difficult to control. The summer spraying programme for apples comprised two pre-blossom applications of lime-sulphur and six post-blossom of a captan/dinocap mixture. Metasystox at 12 oz per 100 gal dilute wash and phenkapton at 16 oz were added at petal-fall and in mid-July respectively for the control of red spider and sawfly. The addition of 25% miscible DDT at the rate of 3 pints per 100 gal to the fungicide spray in mid-June and again in early July gave good control of codling moth. A single spray of 4 lb captan per acre was applied in mid-September to Cox to control gloeosporium rot in store.

A programme of this sort is effective and results in good quality fruit and healthy foliage but is very expensive, costing £25-£28 per acre for chemicals alone. This is probably justified for a high-yielding plantation of Cox, but for varieties of lesser value, such as culinary apples and Worcester, the replacement of the captan/dinocap spray by sulphur would halve the cost of chemicals.

In 1961 pears were sprayed twice pre-blossom with lime-sulphur and twice post-blossom with captan. Metasystox was added at green-cluster for the control of aphid and lead arsenate at petal-fall against codling. Captan was again used as a fungicide throughout on Doyenné du Comice. Because of a severe outbreak of pear sucker in early July all plots were sprayed with metasystox. This, not being immediately effective, was followed a week later with 1 pint per 100 gal of Gusathion. The pest was eliminated, but it is doubtful if the second spray was really necessary as other pears which were sprayed with metasystox only were also cleared of the attack. All plums were sprayed three weeks after petal-fall and again three weeks later with metasystox against aphid and red spider ; for young plums a preparation containing copper oxychloride was added to each of these sprays against bacteriosis. Plum pests seem easily disposed of but bacteriosis and silver leaf remain serious problems. All cherries were sprayed at white-bud with metasystox against aphid and with Bordeaux mixture in mid-September and mid-October. In addition, young cherries were sprayed with Bordeaux mixture and cotton-seed oil in early May and mid-August. It is our experience that these four copper sprays give good control of bacterial canker in cherries but a programme of this sort would seem to make it undesirable to grow plums as an inter-crop in cherry orchards as was frequently practised, owing to the deposit on the plums at picking time.

Raspberries were only sprayed twice in 1961. Once at bud-burst with lime-sulphur, DDT and spreader against aphid and cane spot, and once at pink-fruit stage with malathion against beetle. In an effort to control big bud mite all fruiting black currants were sprayed three times with 1% lime-sulphur at 400 gal per acre. DDT was added to the first spray to control capsid and metasystox to the third for aphid. All fruiting strawberries were sprayed four times and dusted three times with sulphur. This was followed by an application of 5 lb of actual aldrin per acre just before strawing, against beetle, and one of 5 lb captan per 100 gal against botrytis while the plants were in bloom. After picking, when the beds had been cut over and cleaned up, all were again sprayed with metasystox and colloidal sulphur. Sulphur dust was applied twice before flowering and once after to assist with mildew control.

Runner beds and non-fruiting plots were sprayed in early May, at the end of May, and in mid-August with metasystox and dusted with sulphur as necessary.

Arable crops

The area under arable crops remained the same as in 1960 and, in spite of the very wet sowing conditions in the autumn and spring and the summer drought, results were satisfactory. In 1960/61, 50 store cattle were wintered for a neighbouring farmer at a fixed weekly charge instead of buying cattle as has been done in the past. This was a good arrangement and avoided the gamble of market fluctuations. No roots or kale were grown in 1961 as these have proved very expensive to produce on the small scattered pieces of land usually available. An extra 50 tons of pea haulm was obtained from the local factory for feed ; the small pieces of land formerly used for growing fodder were either fallowed or grassed down.

Potatoes.—Yields were low in 1961, probably because of the combined effect of bad soil conditions

at planting time, the late spring frost and the summer drought ; but the absence of blight and the good weather at lifting reduced production costs and largely compensated for reduced yields. Six acres of Craig's Royal were marketed at good prices in August. Nine acres of King Edward probably suffered seriously from lack of rain and the crop, though heavy, contained far too many small tubers. The 2 acres of Stormont 480 were also disappointing and this variety will not be grown again. The 7 acres of Majestic were cut to the ground by frost, but recovered and yielded approximately 9 tons per acre. These and the King Edwards were barn stored and will be marketed early in the New Year.

Cereals.—Thirty one acres of wheat were grown and 11 acres of barley. Of the area under wheat, 5 acres was Professeur Marchall which was grown for seed and threshed at harvest yielding 24 cwt per acre. This was sown under very wet conditions in autumn 1960 and germination was poor. Ten acres of Cappelle also suffered from the wet, some of the germinating seed being completely washed away and the crop of this variety also was patchy and the yield low. The remainder of the wheat was the spring variety Jufy I which yielded 27 cwt per acre. All the barley was Rika which yielded well for the season at 34 cwt per acre.

Peas.—Peas were again grown for canning and quick freezing on 35 acres and cropped well ; 15 acres of Kelvedon Wonder yielded 33 tons 13 cwt, 10 acres of Lincoln 15 tons, 5 acres of Gregories Surprise 8 tons 4 cwt and 5 acres of Perfected Freezer 13 tons 7 cwt. Twenty-eight acres of ryegrass and clover were grown for making into hay and silage. On part of this area there was an abundant second growth of red clover which was harvested for seed.

Experimental nurseries

The atrocious weather in the early months of 1961 greatly hindered all nursery operations. The planting of the maiden nursery area had to be carried out under very wet and muddy conditions, but in spite of this all the 20,000 rootstocks planted grew well, though it was many weeks after planting before a proper tilth could be obtained. Stoolbed work was also difficult and the most strenuous efforts were necessary in order to get all layers pegged down and dusted over with soil before the buds began to break. It was not possible to extend the stoolbeds of virus-tested rootstocks on Park Farm (P1) as much as had been hoped, but a start has been made and a virus-tested clone of Quince A was offered to Members for the first time this year. The weather for harvesting rootstocks was ideal but the crop of some varieties was rather disappointing. Rooting was good but there were fewer shoots and in some cases they were much smaller than last year. The dry summer and prevalence of mildew probably accounted for this.

Despite this poor start, and the dry weather which followed, all 2-year-old and maiden trees grew well and the bud take was excellent. As an alternative to raffia for tying in buds, 1 in. polythene strip has been tried on a small scale over the past three seasons. Results so far have been variable, but efforts to find a successful technique will continue as there are many advantages in using this material.

The buds do not need sealing with vaseline, and as no hot wax is used the troublesome chore of lighting and maintaining a coke fire for heating it is eliminated. For grafting, polythene strip is an unqualified success giving as many if not more successful unions as raffia-tied grafts and at the same time producing a neater, cleaner union which has been proved to heal quicker than a union covered with the normal hot wax.

To provide a stem and crotch resistant to bacterial canker all varieties of plums and cherries which are susceptible to this disease are now high worked on staddles. At first this was a lengthy process which entailed leaving the trees in the nursery for an extra year whilst growing a head suitable for grafting. Now, however, by using specially selected rootstocks, and encouraging the growth of side shoots, it is possible to produce the equivalent of a bush tree with a one-year head as quickly as a low worked maiden tree.

Experimental glasshouses

Further progress in the reduction of excessively high summer temperatures in experimental glasshouses has been limited to the modification of one small dutch light house. In this house two-thirds of the glass has been replaced by a wood-wool pad approximately 2 in. thick one end. Water is supplied through nozzles placed 9 in. above the pad, the flow being controlled by a small solenoid valve operated by a thermostat near the centre of the house ; this thermostat also controls an 18 in. fan fitted in the opposite end. When the fan is running the nozzles keep the wood-wool pad wet, which moistens and cools air drawn through it into the house ; when the glasshouse temperature is lowered to the thermostat setting, both the fan and water supply are turned off automatically. This equipment has given results similar to those obtained in another small glasshouse where jets are used to moisten air before it is drawn through the house.

The mist unit has again been extended to accommodate the ever-increasing number of cuttings rooted by this method. Preliminary trials with various media, sizes of cutting and quantities of rooting substance have, so far, given inconclusive results. However, a method of multiplying quince root-stocks using softwood cuttings with one leaf has been very satisfactory. More than 1,000 hop cuttings and hundreds of *Ribes*, *Prunus* and *Rubus* spp. also have been rooted.

During the winter months and early spring, an experiment on the effect of different strains of verticillium wilt on hops was carried out in part of the teak house. This necessitated the installation of sixty 200 watt lamps to supplement natural light and electric fan heaters to maintain a minimum temperature of 55° F.

Apart from the routine work involved in producing and looking after seedlings and plants for experimental purposes, the main task has been the building and construction of four small glasshouses and four growth chambers; the latter was started in May and is still under construction.

The four glasshouses of the dutch light type are all insect proof. The two larger ones and one of the small ones have alternate side panes of glass replaced with P.V.C. gauze and are for the maintenance of potted plants, and the fourth which has all the side and end panels similarly replaced is for the production of strawberry runners.

In the translucent polyester house the first year of seedling growth has been superior to that in a glasshouse during the summer months but inferior during the remainder of the year, probably due to lower light intensity and lower night temperatures.

During 1960 there has been a slight increase in the number of plants grown in pots and beds. Non-porous pots have been extremely useful, especially so in a year in which we have been short of staff.

Sprays used under glass and outside are applied at regular intervals, although the increasing use of systemic insecticides has reduced the number of applications and labour involved. Under glass, Tedion and TEPP have been used as a mixture with good effect against the glasshouse red spider mite. A new pest in the glasshouses which has not been easily eradicated is white fly, which appears to thrive on a wide variety of plants. DDT smokes have not been very effective, due in part to the gauzed apices of the glasshouses which prevent complete sealing of the house during fumigation ; parathion is efficient but unfortunately persists for only a few weeks which precludes its use, except at certain times, on plants where insects are to be used or reared.

Part II

GENERAL REVIEW OF RESEARCH WORK

WITH LISTS OF PAPERS PUBLISHED DURING THE YEAR

POMOLOGY

Throughout the autumn and winter of 1960/61, heavy and persistent rainfall kept much of the topsoil wetter than field capacity, and often near saturation. Comments on soil moisture tension measurements appear on p. 12. Thanks to our freely draining subsoil, however, no serious damage to fruit trees from waterlogging occurred, though much damage was reported from other areas.

A very late spring frost, on 27/28th May, injured many quite large fruitlets ; but in spite of this, fair crops were harvested. Raspberries and black currants, in particular, yielded well.

Some 29 published papers are listed on p. 12.

Tree fruits

The pomological trials with tree fruits now cover some 82½ acres. Only the major changes or items of interest will be commented on.

Rootstocks

The exceptionally wet autumn and winter provided new information on the relative resistance of rootstocks to waterlogging. Though no damage was recorded on any rootstocks at Malling, severe damage was reported from 11 out of 32 rootstock plots on different soils throughout the country. On these 11 plots about 30% of trees on MM.104 and MM.109 were affected, whereas less than 10% of trees on MM.106, M.II, M.XVI and M.XXV suffered damage. Trees of Cox's Orange Pippin were much less damaged than those of Worcester Pearmain. It appears that collar rot (*Phytophthora cactorum*) was not a major factor in this damage, for Cox and M.XVI which are most susceptible to collar rot suffered least damage. No damage was reported from the 21 other plots, and on well drained soils trees on MM.104 and MM.109 have continued to do very well ; but if fruit has to be planted on land subject to waterlogging it is clearly desirable either to avoid the use of these two rootstocks or to ensure that the land is effectively drained.

Two field trials of Cox's Orange Pippin on a range of vigorous and semi-dwarfing rootstocks, including some dwarfing rootstocks used as interstocks on MM.104, and covering about 5 acres, were planted at Canterbury. A small trial of M.IX and M.XX (another promising dwarfing rootstock) was planted at East Malling.

A report on one of the smaller trials of MM. rootstocks, on an exposed hilltop site, appears on p. 63. A paper on dwarfing apple rootstocks was presented at a symposium sponsored by the Connecticut Pomological Society, U.S.A.

In the 14-year-old trial of semi-dwarfing plum rootstocks, trees on St. Julien A once again carried the heaviest crops. In the younger trial, now 9 years old, trees on Pershore, Marianna and St. Julien A all cropped well.

A review of a plum stembuilder trial shows that high working on a stem of Myrobolan B in order to avoid bacterial canker in the trunk or crotch, does not entail any loss of growth or yield (see p. 61).

Multiplication of the most promising clones of the St. Julien plum and Ankara pear selections is continuing in preparation for compatibility tests, and for a further assessment of the resistance of the plums to bacterial canker.

Interstocks.—A trial of the use of dwarfing interstocks for apples was planted in spring 1961. The scions are Cox's Orange Pippin and Worcester Pearmain, the rootstock MM.104, and the interstocks M.VII, M.VIII, M.IX, and M.26. The same five stocks, worked directly, are also included. There is a subsidiary trial on some filler trees, of the effect of interstocks on suckering of M.VII ; and also a comparison of 3426 and M.XX used as interstocks.

Incompatibility

A review of graft-incompatibility is in the press.

Histology

A paper on stem structure in relation to adventitious rooting of apples and other plants is in the press. As a development of this work, an investigation of anatomy and rooting ability in clonal varieties of *Prunus*, *Diervilla* and *Cotoneaster* is being carried out in collaboration with the Department of Horticulture at Wye College.

Measurements of storage and conducting tissue, including sieve tube size, in phloem of Malling and Malling-Merton apple rootstocks sampled throughout the growing season are in progress. The structure of fibres and fibre-tracheids in roots is being examined in relation to anchorage of apples. The conducting capacity of the fibre-tracheids as measured by their lumen size has also been compared with rootstock vigour.

An examination of varietal differences in leaf structure has been continued.

Histological studies of skin finish, including russeting and cracking are described on p. 9.

Propagation

Sets of trees, budded at 6 in. and 12 in., have been planted on two growers' farms known to be infected with collar rot, at Braintree and Petworth, for observations on the incidence of disease in collaboration with the Plant Pathology Section.

Direct lining out of 18 in. plum cuttings has again proved successful. For a second year apple rootstock cuttings in general have not established so well. Cuttings up to 24 in. long have proved successful and will be used in future trials alongside 24 in. 1-year layers. Severely clipped hedges provide sufficiently vigorous shoots for these longer cuttings but the storage bins must be made deeper to accommodate them.

Long (16 in.) cuttings of M.26, rooted under mist and planted out immediately under sprinklers in 1960, over-wintered somewhat variably. Some attained a height of 3 ft in 1961 but the overall establishment and growth were inadequate.

The poorer growth of maiden apple trees following early budding has been largely overcome by early release of the tie or the use of a readily stretched material (see p. 51).

In the search for cherry rootstocks of reduced vigour many of the dwarf cherry species tried have proved incompatible with our commercial varieties, and very few have survived for longer than five years. Eighty-nine hybrids, multiplied by layering, have been budded in a compatibility test and will be further examined for resistance to bacterial canker. Some 130 mazzard seedlings resulting from crosses between clones of differing vigour have survived bacterial canker inoculations and are being vegetatively propagated for extended nursery trial and retesting for disease resistance when worked with commercial varieties.

Double-worked cherry trees, with intermediate stems of acid varieties, and selected species and hybrids, are being raised on mazzard rootstocks in an attempt to combine the root anchorage of the mazzard and growth restriction of the more dwarfing species.

Mother Tree Scheme

In addition to a regular check on the pomological characters of varieties already issued under the Malling Mother Tree Scheme, other varieties are under observation for possible issue. For example, our virus-tested tree of Stark Earliest bore its first fruits in 1960, but they were striped and poorly coloured and possibly not typical of the best clones of the variety. It will be necessary to see more fruits from this source before making a decision about its release.

Root studies

Construction of the underground root investigation laboratory was completed. The underground portion is about 96 ft long, 7 ft wide and 6 ft 10 in. from floor to ceiling, and has 48 plate glass observation panels 3 ft 6 in. wide and 4 ft deep. Experimental material planted in the winter of 1960/61 included 12 trees of Worcester Pearmain/MM.104, various other apple and plum trees and 8 blackcurrant bushes. Observations and records of root growth were made weekly on all windows. Records of shoot growth, soil temperature and soil moisture tension were also taken regularly.

Studies were made of methods of estimating root length, with the help of the Statistics Section, and of the effects on root growth of intermittent illumination with the lights used during recording. Observations were also made on the localized drying of the soil in areas exploited by roots, and attempts were made to find a way of estimating the water content of small areas of soil immediately behind the observation windows.

With the aid of a microscope, observations were made, through the glass windows, on the exudation of droplets of liquid by the root hairs of apple and on the irregular development of root hairs of Myrobalan B. The blackcurrant roots were colonized in June by currant root aphids (*Eriosoma ulmi*) which have persisted into November. The presence of eelworms on the roots of apples, plums and blackcurrants was noted. Many photographs and photomicrographs were taken during the year and the growth of roots was studied by means of time-lapse photography.

Fruit thinning

Preliminary trials were made with 1–napthyl N-methyl carbamate (Sevin) as a thinning agent for apples. A clear thinning response was shown by Worcester Pearmain.

Pruning and shaping

A pruning trial has been planted with Victoria plum on the semi-dwarfing St. Julien A rootstock to compare summer-pruned pyramid trees with unpruned trees and with normal half-standard trees. A report on the first trial of these methods on Victoria on the vigorous Brompton rootstock appears on p. 57.

A pear pruning trial was started on 4-year-old trees of Conference on Quince A and Williams' Bon Chrétien/Beurré Hardy/QA. It compares the Hawke's Bay multiple upright leader system (see 1959 Annual Report p. 120) with open-centre established-spur and open-centre renewal pruning methods.

Growth studies

A new series of studies of growth, flowering and fruiting in relation to branch poise has been begun, on young and mature apple trees. This information will be of special interest in relation to modern tree forms and pruning systems. On mature trees, selected branches of different poise are being recorded in detail, and a photographic record of the changes in tree shape during the growing season and over a number of seasons is being made.

In order to examine the effects of extremes of orientation with respect to gravity, young apple trees are being grown in upright, horizontal and inverted positions. Experiments are also in progress on the effects of bending, on branches and on whole trees; the effects of time and direction of bending are also being studied. An experiment with Myrobalan B on the effects of the degree of bending includes treatments ranging from the unbent tree to one in which the main stem and all laterals are looped.

The preliminary indications are that bending or extreme changes in orientation bring about alterations in the pattern of vegetative growth, changes which in turn influence fruitfulness.

Spacing

An apple tree spacing trial covering 25 acres has been planted on a grower's farm at Brenchley. The trees are planted at two densities ; permanent trees on MM.104 are planted at 24 ft square in the low density plots, and at the same distance in the medium density plots but with a filler tree on M.VII in the centre of each square of permanent trees making the distance 17 ft square. Earlier work has shown the advantage of closer planting in an exposed site and the new trial is to test similar spacings in a less exposed site.

Biennial bearing and the analysis of fruiting

It has been shown that the effect of fruit in preventing the formation of flower buds in the biennial apple variety Miller's Seedling is exerted to a greater extent down the branch than upwards. In the lower part of a branch, the spurs are affected not only by the fruits they carry, but also by the fruits higher up on the branch and by fruits on other branches of the tree.

A comparison of the development of spur buds throughout the season on a regular bearer and on two biennial varieties of apple showed marked differences between all varieties. These differences are being studied in relation to growth and cropping habits of the trees.

Preliminary trials on the use of gibberellin and kinetin to control flowering in apple were begun this season in a search for a material which might influence the process of flower formation without affecting the development of the current season's crop.

Skin finish

The structure of the cuticle, epidermis, and hypodermis of fruits is being examined in relation to russeting and cracking of apples and pears, and cracking of plums and cherries. For this work fruits were sampled at intervals during the growing season.

The presence in the epidermis of small necrotic areas—usually consisting of only a single cell—may be of importance in the development of russet in apples. These dead cells are scattered throughout the entire epidermis of russets. Areas of weakness occurring in the cuticle of russets, and of semi-russet varieties such as Cox's Orange Pippin, may also have a bearing on the formation of the corky tissues.

The surface wax which gives rise to the bloom of apples and plums was studied by a carbon replica technique at the Botany School, Oxford, through the kindness of Professor C. D. Darlington and Dr. B. E. Juniper. Examination of replicas of fruit skins with an electron microscope showed that two structural types of surface wax occurred, one being typical of apples and pears, and the other of plums. The effects of removing the wax by polishing, and by wax solvents, was studied in addition to the regeneration of bloom following polishing.

Herbicides

Simazine at $2\frac{1}{2}$ and 5 lb per acre and monuron at 5 and 10 lb per acre have been applied for a second season to a range of young apples and pears. No injury has been found on the apple trees and damage seen the previous year on Conference pear has not been repeated, Doyenné du Comice guard trees however have shown symptoms of monuron injury.

The effects on trees of diquat and paraquat are being studied. A plot containing a range of trees and stocks is being planted for preliminary testing of other herbicides.

Breeding

Crosses made this spring were designed to produce new early varieties and russets of high quality. Families raised with the same object in 1960 have been stringently selected for disease resistance. Of some 2,300 apple seedlings, selected as late leafing and disease resistant from about 50,000, some 400 flowered and fruited during the year and a high proportion proved to be late in season of flowering. The fruits are being examined for indications of promise as new scion varieties. A comparison of the seedlings growing on their own roots with duplicates growing on M.IX or 3431 has amply confirmed that the use of a dwarfing rootstock markedly shortens the juvenile period in apple seedlings.

In the transference of a major gene for resistance to apple scab, crosses were made between English apple varieties and a backcross derivative of *Malus floribunda* bred by Dr. Shay ; the co-operation of the John Innes Institute in supplying pollen for making these crosses is gratefully acknowledged. The search has also been continued for sources of resistance to apple mildew among open pollinated seedlings of a number of *Malus* species.

A section on rootstocks for pome and stone fruits was contributed to the Handbuch der Pflanzenzüchtung (E562).

Varieties and clones

All Laxton's Superb pear trees, cotoneasters and hawthorns were grubbed, to avoid risk of their acting as hosts for fire-blight infection.

Most plums carried moderate to good crops, in spite of some frost damage in the spring. In the variety and rootstock trials, Victoria carried 110–130 lb per tree, and in the 13-year-old manurial trial 170 lb per tree. Trees of Ontario, 23 years old, carried 240 lb and Warwickshire Drooper and Comte d'Althanns 210 lb ; 14-year-old trees of Cambridge Gage carried 70 lb per tree.

In the newer variety trial on Newgates, planted 1956-57, Severn Cross, Anna Späth and Pershore Yellow Egg all carried 25 lb per tree, and Victoria 40 lb.

Small fruits

The area of small fruit trials is 6·8 acres.

Variety and strain trials

Strawberries.—A trial, now in its third year, showed that plants of a heat-treated clone of Early Cambridge, although larger, continued to produce fewer blossoms than those of a non-treated clone.

A trial has been planted to compare the growth and cropping of a virus-free clone of Cambridge Favourite, only recently available, with two other virus-tested clones now extensively planted in commerce.

Loganberries.—The new trial of virus-tested loganberry clones which includes LY59 and three other previously untried clones, bore its second crop this year. All clones yielded well at approximately $3\frac{3}{4}$ tons per acre.

Blackberries.—Although both clones of Bedford Giant cropped quite heavily this year, the fruit of the thornless clone was small and lacking in firmness and the leaves showed much yellow mottling.

Propagation and maintenance of stocks

Strawberries.—The variety and clone collection and three runner beds were maintained as usual. All the clones of Climax which had remained green for the first two years following propagation by disc cuttings showed ' yellows ' in 1961.

Black and hybrid berries.—Several clones were again propagated. Shoot growth from tips rooted this summer has been particularly vigorous.

Breeding

Raspberries.—Breeding for resistance to *Amphorophora rubi*, the rubus aphid, in collaboration with the Entomology Section, was continued. Three new genes have been identified ; two of these independently confer resistance to strains 2, 3 and 4 of the aphid (and presumably to strain 1 also), the third governs resistance to strains 3 and 4. New crosses have been made with the object of producing a range of loganberry type hybrids.

Currants.—In transferring big bud mite resistance from gooseberry to black currant, currant-gooseberry tetraploids of BBBG composition were successfully crossed with diploid and tetraploid black currants. Breeding for improved strig characters has continued ; the synthetic tetraploid of Baldwin × *Ribes longeracemosum* was successfully backcrossed to a tetraploid seedling of Baldwin. A paper on interspecific hybridization in *Ribes* has been prepared for publication.

Gooseberries.—In transferring spinelessness from the black currant, some 2,000 flowers on a range of gooseberry varieties were pollinated by a spineless black currant-gooseberry triploid of BGG composition ; 211 seeds were obtained. Crosses and selfs of hybrids involving Hunter's semi-spineless gooseberries and large-fruited English varieties have been segregated for partial spinelessness and for American gooseberry mildew resistance ; these are being selected for improved fertility, fruit size and mildew resistance.

Cytology.—Routine chromosome counts on varieties, species and hybrids of *Rubus* and of *Ribes* have been made. A study of chromosome morphology and of nucleoli in black currants and gooseberries and in their hybrids has been completed.

Cultural measures

Strawberries.—Owing to a severe outbreak of verticillium wilt in the manurial trial planted last year in collaboration with the Fruit Nutrition Section, the original plants of Cambridge Rearguard have been replaced by Talisman, which shows a high degree of field tolerance to this disease.

The first crop was harvested from a trial of July planted Redgauntlet in which freshly dug runners are being compared with others held in store from February until the time of planting. Plants from both sources grew well and yielded over three tons per acre at the normal plant spacing of $3 \times 1\frac{1}{2}$ ft. Further work on the utilization of cold-stored runners included a test of the feasibility of producing a crop in August from runners planted in June. The results obtained from unirrigated plants under the hot and dry conditions of 1961 were disappointing.

A trial has been planted to study plant response to time of defoliation in the varieties Redgauntlet and Cambridge Favourite.

In collaboration with the Plant Pathology section a field trial has been laid down to study the effects of fumigating the soil with chloropicrin and sodium methyl dithiocarbamate on strawberry growth and cropping and the incidence of verticillium wilt.

Herbicides

Strawberries.—Simazine has been used on a strawberry runner bed at $\frac{1}{2}$ and 1 lb per acre, applied at the beginning of runnering in June. Both rates gave excellent weed control and there was no reduction in the number of runners produced. The fruiting of these runners is to be studied.

Black currants.—$2\frac{1}{2}$ and 5 lb simazine have for the third successive year given no reduction in yield. The yield from the plots receiving 5 lb simazine was significantly greater than from those given ' normal cultivation '.

Raspberries.—On raspberries also simazine applied at $2\frac{1}{2}$ and 5 lb per acre has, for the third successive year, given no significant reduction in yield.

A plot of a range of soft fruits is being planted for preliminary herbicide testing.

A paper reporting the progress of trials with simazine and monuron was presented at the Fifth British Weed Control Conference (E559).

Frost damage investigations

Two spring frosts caused much damage. A frost on the night of 19th/20th March (screen min. 24° F, grass min. 19° F) killed peach blossoms on bush trees and many flower buds and even spurs on

pear trees, reducing the crop. Black currants were also damaged but, in spite of this and heavy run off in early May, cropped quite well.

The exceptionally late frost on 27th/28th May (screen min. 30° F, grass min. 26° F) caused damage to apple fruitlets, already ½ in. in diameter, and in some cases also to spurs and young shoots, The fruit set was relatively light and crops were reduced ; the quality was also lowered by internal browning, caused by the frost. Strawberry flowers and young fruitlets were also damaged, and frost damage to raspberry blossom resulted in a proportion of misshapen fruits. The frosts did not reduce the plum crop, although the variety Victoria showed gumming, frequently internal only, and frost marks were common on other varieties.

Experiments on protective sprinkling of apples and black currants were continued. In apples, internal damage to fruitlets from the late frost was prevented by sprinkling. In black currants, the frost was not serious enough to reduce the crop, but it was confirmed that, at the early grape stage, black currants need a higher precipitation rate than apples, for effective protection.

Following frosts, gibberellic acid in various concentrations was applied this year to various fruit species. Pears responded best to the treatments, producing seedless fruits of full size, particularly with Packham's Triumph which was the most severely damaged by frost. Stone fruits (cherries, peaches and plums) initially responded well to high GA concentrations by rapid growth, but many dropped prematurely.

The results of laboratory experiments on the interaction of gibberellic acid with other growth substances to induce fruit set in apples suggests that these should be continued.

Four papers were published, E530, E536, E547, and E551.

Walnuts

The late frost in May did surprisingly little damage to walnuts. However, there was little blossom this year, and crops were only light.

Horticultural meteorology

The usual meteorological records were maintained (see p. 67).

Some additional instruments have been installed on the meteorological plot including a Dines tilting siphon rain recorder which records duration and intensity of precipitation, a seven day thermograph with large drum, a weekly hygrograph, and new soil thermometers installed under grass at depths of 1, 2 and 4 ft.

A Surface Wetness Recorder, giving a continuous record of hours of wetness mainly for estimating apple scab infection periods (' Mills Periods ') was in use throughout the summer.

The soil moisture tensiometers, under bare soil, on the Meteorological Plot showed that the soil at a depth of 8 in. was wetter than field capacity throughout the five months October 1960 to February 1961, and reached complete saturation for many days. At 20 in., however, the soil remained at about field capacity throughout the winter.

Publications during the year

E525 Mosse, Barbara, and Labern, M. V. (1960). **The structure and development of vascular nodules in apple bud-unions.** *Ann. Bot., Lond., N.S.*, **24**, 500-7.

E527 ——— (1960). **Graft incompatibility in plums ; observations on a ten-year-old field trial.** *J. hort. Sci.*, **35**, 260-5.

E528 ——— (1960). **Further observations on the effects of ring-grafting peaches with an incompatible rootstock variety.** *J. hort. Sci., 35*, 275-81.

E529 Keep, Elizabeth. (1960). **Amphiplasty in *Ribes*.** *Nature, Lond.*, **188**, 339.

E530 Modlibowska, Irena. (1960). **Breaking the rest period in black currants with gibberellic acid and low temperature.** *Ann. appl. Biol.*, **48**, 811-16.

E531 Glenn, Elizabeth M. (1961). **Plum rootstock trials at East Malling.** *J. hort. Sci.*, **36**, 28-39.

E532 McKenzie, D. W. (1961). **Rootstock-scion interaction in apples with special reference to root anatomy.** *J. hort. Sci.*, **36**, 40-7.

E534 Garner, R. J. (1960). **Fruit tree raising today.** *Nurseryman and Seedsman and Glasshouse Grower*, **131**, 594-5.

E536 Modlibowska, Irena. (1961). **Stimulation of fruit development in frost damaged pears.** *Rep. E. Malling Res. Sta. for 1960*, 46-8.

E537 Smith, N. J., and Rogers, W. S. (1961). **Higher budding of apple rootstocks.** *Rep. E. Malling Res. Sta. for 1960*, 49-51.

E538 GARNER, R. J., and HATCHER, E. S. J. (1961). **Delayed flowering of trees raised from adventitious scions.** *Rep. E. Malling Res. Sta. for 1960,* 52-3.

E539 GARNER, R. J., and NICOLL, CATHERINE P. (1961). **The compatibility and growth of pear scions on apple rootstocks.** *Rep. E. Malling Res. Sta. for 1960,* 54-6.

E540 MOSSE, BARBARA. (1961). **Graft incompatibility in plums : interactions between the varieties Victoria, President, and Myrobalan B.** *Rep. E. Malling Res. Sta. for 1960,* 57-60.

E541 TROWELL, G. F. (1961). **Weather conditions during 1960.** *Rep. E. Malling Res. Sta. for 1960,* 61-4.

E542 PRESTON, A. P. (1961). **Fruit growing in Northern Italy.** *Rep. E. Malling Res. Sta. for 1960,* 123-9

E543 GLENN, ELIZABETH M. (1961). **Rootstocks for plums.** *Rep. E. Malling Res. Sta. for 1960,* 130-1.

E544 ROWE-DUTTON, PATRICIA, and GARNER, R. J. (1961). **Mist propagation : some problems and possibilities.** *Park Administration,* **26,** 37-43.

E545 MCKENZIE, D. W. (1961). **A note on vessel structure in the xylem of roots of M.XVI apple rootstock.** *J. hort. Sci.,* **36,** 138.

E546 KNIGHT, R. L., and KEEP, ELIZABETH. (1961). **Obst-Züchtung. Beerenobst : *Ribes* L. Subgenera : *Ribesia, Coreosma* und *Grossularia* Part III. Grundlagen und Methoden der Züchtung und Zuchterfolge Subgenus *Coreosma*.** *Handbuch der Pflanzenzüchtung,* 2. Auflage, VI. Band. 450-60.

E547 ROGERS, W. S., and MODLIBOWSKA, IRENA. (1961). **Practical frost protection of fruit by water sprinkling.** *Grower,* **55,** 658-61. Reprinted in French—*La Pomologie Francaise,* **3,** 101-8.

E549 KEEP, ELIZABETH. (1961). **Autumn-fruiting in raspberries.** *J. hort. Sci.,* **36,** 174-85.

E550 KNIGHT, R. L., and KEEP, ELIZABETH. (1961). **Obst-Züchtung. Beerenobst : *Rubus* L. Subgenera : *Idaeobatus* Focke und *Eubatus* Focke. I. Systematics. II. Floral Biology and seed formation.** *Handbuch der Pflanzenzüchtung,* 2. Auflage, VI. Band. 477-87.

E551 MODLIBOWSKA, IRENA. (1961). **Effect of soil moisture on frost resistance of apple blossom, including some observations on ' ghost ' and ' parachute ' blossoms.** *J. hort. Sci.,* **36,** 186-96.

E553 PRESTON, A. P., and ROGERS, W. S. (1961). **Some Malling and Malling-Merton clonal apple rootstocks.** *' Size Controlling Apple Rootstocks ',* a symposium sponsored by the Connecticut Pom. Soc., University of Connecticut, 31-42.

E554 ——— (1961). **The free palmette.** *Amat. Gdng.,* **78,** 12.

E556 ——— (1960). **Résultats d'essais de taille sur pommiers à East Malling.** *Fruit Belge,* **230,** 145-52.

E562 TYDEMAN, H. M. (1961). **Fruit tree rootstock breeding. Apples, pears, cherries, plums, peaches, apricots, and almonds.** *Handbuch der Pflanzenzüchtung.* 2, Auflage, VI. Band. 547-72.

E561 HOLLOWAY, R. I. C. (1960). **Tests of 2,4-DES, CIPC and dinoseb on Royal Sovereign strawberry.** *Proc. 4th Brit. Weed Control Conf.,* 108-11.

E559 ——— (1961). **A progress report of trials with simazine and monuron on some fruit plants.** *Proc. 5th Brit. Weed Control Conf.,* 367-71.

STATISTICS AND RECORDS

Design and analysis

No fewer than 1,210 bodies of data were analysed, 289 on the electronic computor at Rothamsted and 921 on calculating machines. Each of these figures is the highest recorded, previous maxima being 942, 227 and 836 respectively. The increase was partly due to special requests from the Fruit Nutrition Section which are unlikely to recur, and partly to more requests having been received from the N.A.A.S. Many of the variety trials of the National Fruit Trials are now mature ; this part of the increase is likely to be permanent. Such variety trials require much tedious summarization before analysis can begin. As a result of these difficulties there were 186 bodies of data still awaiting attention at the end of the year.

The developments in design of experiments referred to in last year's Report are now accepted as routine ; convenient methods of analysis have been evolved and are already in use. For some experiments use is made of the Elliott 401 electronic computor to work out some of the constants of the design, a programme having been written for this purpose with the help of workers at Rothamsted.

The systematization of the computing methods used in the Section is being extended with a view both to economizing labour and to extending the range of operations that can be regarded as routine.

During the year members of the Section have lectured regularly at Wye College on experimental design and the analysis of data and have given advice on these topics to research workers at the college.

Record Office

The catalogue of completed experiments has been finished though much work remains if full use is to be made of it. Historical studies have continued in collaboration with the Fruit Nutrition Section and a report prepared (see p. 85).

Statistical Research

Methods of experimental design and analysis

A new classification of experimental designs is being evolved, because it is felt that the conventional classification places emphasis on designs of little practical use while ignoring others that are potentially useful. The general class of designs referred to last year is included in this new classification, which is based on the method of analysis.

A report (M53) has been published on another new class of design intended to give specially good comparison of a control with the other treatments, or, by sacrificing precision of these comparisons, to allow better comparison between the other treatments. These designs are also of use when adding a new set of treatments to an existing trial.

Work is continuing on the analysis of data from experiments where blocks contain varying numbers of plots.

A report (M59) has appeared on regression problems in which there is a sudden change in the relationship between the two quantities. This study, reported last year, is forming the basis of a much wider investigation into growth relationships.

Statistical studies of biological problems

A detailed study of the sources of variation in apple tree experiments has been completed and a report prepared. It appears that much of the variation comes from factors inherent in the trees themselves and a start has been made on the study of these factors (see p. 87).

An extensive investigation was begun into form and growth relationships in fruit trees, both young and mature. This will include investigation of the effects on these relationships of the chief cultural practices, and is a continuation of work already published (M17, M25, M30, M49). As in other biometrical studies it is intended to make considerable use of multivariate methods of analysis.

A detailed study has begun on results from the apple uniformity trial begun in 1950 ; analysis of this great quantity of data has been transformed by the development of multivariate methods and the availability of an electronic computor.

An account of the various techniques of multivariate analysis that are in use in the Section for the elucidation of biological problems is in the press, special attention being given to growth measurements and the chemical contents of apple leaves.

Studies have been made of monthly rainfall patterns at East Malling with a view to estimating the probability of any particular range of patterns occurring.

Work has started on forecasting the time of picking of Beauty of Bath apples on the basis of blossom dates and subsequent temperatures.

Data have now been collected on which it is hoped to base methods of calibrating black currant and raspberry crops.

Field trials

Recording of the apple uniformity area has continued. The trial on the restoration of soil uniformity, conducted in collaboration with the Fruit Nutrition Section (see p. 23), has been rigidly pruned to restrict variation of form and size.

PUBLICATIONS DURING THE YEAR

M53 PEARCE, S. C. (1960). **Supplemented balance.** *Biometrika*, **47**, 263-71.

M58 FREEMAN, G. H. (1961). **The analysis and interpretation of experimental results.** *The Incorporated Statistician*, 1-24.

M59 SPRENT, P. (1961). **Some hypotheses concerning two phase regression lines.** *Biometrics*, **17**, 634-45.

PLANT PHYSIOLOGY

Horticultural control of tree performance requires knowledge of the natural mechanisms at work in the tree—how does the rootstock influence the scion, how is dry weight distribution determined, for what substrates do fruits and shoots compete, and so on? Certain aspects of this knowledge may be acquired by experiments planned to answer specific questions with precision, paying great attention perhaps to a few crucial measurements ; such experiments tend to use small trees and refined methods (for example the use of radio-active carbon to follow the movement of photosynthates). Certain other aspects, however, necessarily require the inclusion of the mature cropping tree in our experimental purview ; it is to be hoped that the somewhat different methods of approach needed for these contrasting types of experimentation will each supplement the other.

This report exemplifies the two kinds of approach in several problems, and also draws attention to the extreme treatments which are often applied in order to obtain large responses, even though they may be well outside the range recognized in horticultural practice.

Distribution of dry weight in the tree

Analysis of the data from the ' stock-on-stock ' experiment continued, and a short paper has been submitted describing one of the most striking of the results—the great regularity of the pattern of distribution of each year's increment among the growth regions of the tree, despite large differences in growth and form of the various combinations of rootstock and scion. Cropping in this experiment was not heavy, but it resulted in decreased root growth and increased leaf efficiency.

More precise studies on 2-year-old potted trees showed similar results : trees deblossomed or defruited at the end of May put on much the same total dry weight during the season as cropping trees, but in these half the increment was crop, and of the non-crop fractions root growth was the most severely reduced. Leaf efficiency was higher on the cropping trees, but this may have been due to a greater proportion of spur leaves increasing the average duration of leaf activity, rather than to a higher yield of dry matter per unit area of leaf (see also p. 81 of this report).

The sensitivity of the root to treatments on the shoot was also illustrated by experiments mentioned in these notes last year, in which leaf efficiency was lowered by red spider mite attack (p. 77). A similar experiment was carried out this year largely by the Entomology Section (p. 34). Final results are not yet to hand, but measurements taken during the season showed that shoot growth was reduced by mite infestation at an earlier stage than visible damage would have suggested, thus confirming previous observations. Water loss from detached leaves bronzed by feeding mites was greater than from green leaves.

Pending the use of $C^{14}O_2$ to trace the distribution of photosynthates to the site of utilization in the tree, an experiment was carried out in which sites of production or utilization were modified by drastic surgical treatments. For example, on three occasions after growth was well under way, all leaves except those in a particular zone were removed from potted trees to ascertain whether assimilates from that region were used preferentially in any particular part of the plant. Similarly roots were pruned so as to remove either the recently formed root, or half the complete system ; from other trees half the bark was stripped from the old stem to reduce the cambial surface available for the production of secondary thickening. Final data are not yet available, but in all cases when a plant component has been reduced the remainder has made some compensatory growth : even old leaves near the base of the stem increased in dry weight when the rest had been removed, while halving the cambial area of the old stem had no effect whatever on the total increase in weight of the stem or the whole plant. That such drastic treatments did not greatly modify the pattern of growth suggests that shifting this pattern towards more fruit per unit increment will be difficult.

Winter loss in tree weight has often been observed, and this year it was considered in relation to the theoretical effects due to the different amounts of living tissue in various rootstocks ; while no hard and fast conclusions could be drawn, theory and observation were sufficiently in accord to justify further experimental work.

The experiment planted in 1959-60 to compare growth following pruning at different times, both in the growing and the dormant seasons, will be concluded this winter. Results so far show that during the first year trees pruned in June added nearly as much weight as those unpruned after planting, and in the second year may well exceed them. Extreme pruning treatments far beyond the ' horticultural ' range have been practised in the small experiment described on p. 81.

Another example of extreme modification of tree form is the experiment to assess the effect of

stem length on shoot extension and trunk thickening ; two years ago 1, 3, 5 or 7 rooted layers of three rootstock varieties were inarched one above the other to produce stems varying in length from 3 to 15 ft but of the same age throughout. Last year the plants were successfully established on the basal root system alone, and this year extension growth was permitted from the top only, all other lateral shoots being rubbed out as they appeared. Records of growth and thickening are not yet complete, but the mere survival of the dwarf variety 3426 on a 15 ft stem rules out the possibility that a factor in dwarfing in this rootstock is inefficient stem transport, in either direction.

Growth of shoot grafts in the cherry rootstock discrimination experiment again indicated that the John Innes seedlings under test were severely ' shoot-limited ' ; the improved root grafting technique was not as successful as in its trial year and many grafts were lost through gumming.

Even when it is planned to measure growth as increase in dry matter, experiments would often be simpler and more precise if dry weight could be reliably estimated at the start of an experimental period from non-destructive measurements. Work along these lines has continued, and relations between dry weight of the shoot and the lengths and diameters of its parts have been established ; in the course of these studies changes in the fresh weight to dry weight ratio were observed in various regions of the shoot, which were possibly associated with incipient dormancy.

Growth and form in terms other than dry weight

The experiment to estimate the effect of cropping on growth has continued through its ninth season. Most of the plot escaped serious frost damage but the crop was light nevertheless. The behaviour of the two biennial varieties is complicating the handling of the data, because the trees are not all in phase : last season, of the trees on M.IX all 8 hard-pruned trees of Miller's Seedlings were ' off ', but one of the lightly-pruned trees was ' on ' ; in the Laxton's Superbs, on the other hand, 6 of the 8 hard-pruned, and half of the lightly-pruned trees were ' on '. On M.XVI hard pruning has resulted in small but regular crops from both varieties, but the lightly-pruned Laxtons were all ' on ' when the Millers were all ' off '. Recording of sample branches on the trees on M.XVI has proved satisfactory, but the whole tree still has to be deblossomed, and on such large trees this is difficult to complete in the short time which is so desirable from an experimental viewpoint.

Work on the development of the leaf canopy in the orchard has been discontinued until the appointment of new staff.

A further experiment was conducted on vegetative Crab C shoots to clarify the effect of the subtending leaf on the development of the meristem in its axil. A paper (p. 71) describes the results obtained both this year and last.

To obtain information about the effect of temperature on the rate of production of leaves from the apex of a vegetative shoot, well-established Crab C plants in pots were grown outside or in a greenhouse with heat to prevent the temperature falling below 70° F, and after calibration, half the plants were switched from each environment to the other. Measurements three times a week showed the short-term growth responses to temperature fluctuations, and the longer-term changes in rate of leaf production in the two environments. During the month following transfer (on 14th August) the greenhouse plants experienced a total of 881 accumulated day degrees above 42° F and added 15·4 new leaves to the shoot, while the plants outside produced 8·0 new leaves in 565 accumulated day degrees.

Further attempts have been made to obtain wide-angled branches on maiden trees, and on F12/1 rootstocks for staddle production. Since gibberellic acid (GA) and kinetin are known to affect bud dormancy and apical dominance in some plants, these two chemicals were tested on shoots of Cambridge Gage and Napoleon cherry with or without ' tip defoliation '. Neither alone nor together was there any effect on bud growth, but the gage responded dramatically to GA at 1,000 p.p.m. by greatly increased extension of the main axis; the severe check imposed by removing seven young leaves was completely overcome by the GA, and the results as a whole suggest that young leaves of this variety produce suboptimal amounts of a gibberellin-like substance required for internode extension. It is unlikely that this response will have any practical application, but its experimental value might be considerable. F12/1 rootstocks for staddle production branch naturally toward the base of the stem, but the upper buds (at the height required for the branch framework) will not break in the current season even when the main shoot is decapitated. GA successfully induced these buds to break, but the application was too late to obtain much growth of the branches, and in any case they tended to be at a narrow angle. Further trials will be made next year.

The importance of spray materials in tree performance

With the previous year's results as a guide, greater precision was introduced into this year's experiments on the effect of early leaf damage on growth or cropping. To assess the effect on growth,

M.IV rootstocks were sprayed with 2% lime-sulphur on 1, 2, 3 or 4 occasions and samples taken at intervals to determine the rate of growth. The recovery from the damaging effect of the spray observed last year was again found, and it was further shown that after recovery sprayed plants continued growth at the same rate as the unsprayed.

The effect on fruit drop and final crop of damaging the spur leaves of three apple varieties by spraying them with 2½% lime-sulphur at green cluster and pink bud, was compared with that of removing these leaves at the time of spraying. Two experiments were performed and both gave the same result : compared with the untreated trees defoliation had little effect on Laxton's Superb, but decreased the crop of Worcester Pearmain by 65% and of Cox's Orange Pippin by 82%. Lime-sulphur caused visible scorch to the leaves of Laxton but increased the crop by 20% ; a similar amount of scorch on Cox, accompanied by increased early fruit drop, was compensated for by reduced drop later in the season, so that yield was not affected. The Worcester trees showed no visible damage but a small increase in early drop ; reduced drop later resulted in a crop increase of 20%.

Since so many sprays have ' side effects ' on the tree apart from the purpose for which they are applied, it was encouraging to find that sprays of Tedion and metasystox applied to Crab C plants to keep them free of red spider mites did not affect growth ; if later results substantiate this finding, it may allow greater scope in experimentation on mite damage, since control plants can readily be kept free of attack by this means, but doing so by hand picking is very tedious.

Carbohydrate resources

It seems to be difficult to change the pattern of accumulation of carbohydrates in the tree except by rather drastic treatments such as branch ringing to interrupt translocation. While movement of carbohydrates will be very largely reduced by the ring until it is bridged by new tissues, other factors concerned with growth may also be affected. This year, therefore, the method has been under investigation prior to its probable use in later experiments.

The dangers of ringing were seen in some extreme treatments applied to rooted apple stoolbed shoots : when these single-stemmed plants were ringed at the base after they had produced about 10 leaves, subsequent shoot growth slowed up, the leaves became chlorotic, prematurely developed autumnal colouring, and in many cases died ; when the roots were washed out they were found to be very poorly developed. Half the plants had had the roots trimmed off at planting, and these suffered first and most from ringing. Ringing after 10 more leaves had expanded was still deleterious, but not so severely ; when the ring had been bridged root and shoot growth were greatly improved.

Preliminary attempts were made on another set of plants to find a means of introducing solutions into the transpiration stream over long periods with the possibility in mind of supplying some of the nutritional or hormonal substances which ringing had interfered with, and thereby discovering what kind of material is limiting the growth of ringed plants. Such attempts have not so far been successful.

In other experiments on well-established Y-shaped trees, one or both branches were ringed, and some were allowed to carry fruit ; the effect on the carbohydrate resources in different parts of the tree is being followed. Branch-ringing was carried out at various times on two 9-year old trees of each of four apple varieties on M.XVI to ascertain the effects on cropping and extension growth. Even though rings made in March, April or May usually healed by late summer, pronounced effects persisted into the second and third years after treatment. When all samples have been analysed it should be possible to see what place carbohydrates have had in the imposed growth pattern, and from this perhaps infer what their role is in the intact tree.

Shading was again used in attempts to modify the accumulation and utilization of carbohydrates, but whereas before only vegetative plants were employed and the effect of treatment assessed during the same year, small potted trees of Sunset on M.VII, capable of fruiting, have been shaded at various stages this year ; the effects of these treatments will be observed in 1962.

Direct measurement of CO_2 exchange has again been held up, but opportunity was taken to redesign the apparatus slightly to make it more versatile. Some practical and theoretical studies of boundary layer effects at the leaf surface were carried out, which elucidated certain difficulties encountered in earlier work.

Natural formative and growth controlling substances

The A.R.C. Unit of Growth Substances and Systemic Fungicides at Wye College had to abandon the work on the purification and identification of the inhibitor of cell extension extracted from Myrobalan shoots, but pending assistance with this project, a further supply of 300 mg of partially purified material has been obtained this year from nearly 60 kg of shoots. A modified continuous extraction process was adopted which saved both time and solvent, and a corresponding increase in chromatographic capacity

was achieved by constructing a ' chromatopile ' apparatus, which has proved very useful. After chromatography in two different solvent systems, the inhibitory fraction was recovered by large-scale Soxhlet extraction. Additional steps in purification have not so far been successful.

Earlier work on the effect of this inhibitor on respiration of coleoptile sections was confirmed and extended : at concentrations which brought about a 50% inhibition of growth there was no effect whatever on either basic or ' IAA-induced ' respiration.

In preparation for a further extraction programme in the coming winter, a careful comparison showed that dried shoots—in many ways the most convenient material—yielded less inhibitor than fresh or deep-frozen shoots.

An attempt was made by a bark ringing technique to intercept growth substances passing down to or up from the roots of Myrobalan plums grown in sand culture. Ether extracts were made of bark samples adjacent to the rings at intervals after treatments. There was no evidence of a growth substance effective in the coleoptile section test moving upward in the bark, but, particularly at 6 and 24 hr after ringing, there was some increase in a promoter of cell extension above the ring and disappearance below.

Some further work was done on the possible importance of phloridzin residues in the soil, in relation to the apple replant problem ; once again there was little deleterious effect even of very heavy and frequent doses on apples in sand culture, but in solution culture roots rapidly succumbed. This appeared to be a secondary effect of bacterial growth in the culture solutions preventing effective aeration ; comparable plum cultures were not available to run in parallel, so that it is not yet known whether this reaction between micro-organisms, phloridzin, and a root system in solution culture, is specific to the apple.

Publications during the year

F115 Maggs, D. H. (1960). **The stability of the growth pattern of young apple-trees under four levels of illumination.** *Ann. Bot., Lond., N.S.* **24,** 434-50.

F116 Barlow, H. W. B., Hancock, C. R., and Lacey, H. J. (1961). **Some biological characteristics of an inhibitor extracted from woody shoots.** *IV Int. Conf. Plant Growth Regulation.* Iowa State Univ. Press, 127-40.

F117 Knight, R. C. (1961). **Taper and secondary thickening in stems and roots of the apple.** *Rep. E. Malling Res. Sta. for 1960,* 65-71.

F118 Barlow, H. W. B., Hancock, C. R., and Lacey, H. J. (1961). **An artefact in a coleoptile straight growth assay method.** *Rep. E. Malling Res. Sta. for 1960,* 72-6.

F119 Maggs, D. H. (1961). **Changes in the amount and distribution of increment induced by contrasting watering, nitrogen and environmental regimes.** *Ann. Bot., Lond., N.S.* **25,** 353–61.

F120 Hancock, C. R., Barlow, H. W. B., and Lacey, H. J. (1961). **The behaviour of phloridzin in the coleoptile straight growth test.** *J. exp. Bot.,* **12,** 401-8.

K112 Gorrod, A. R. N. (1961). **Sorbitol metabolism in apple fruits.** *Nature, Lond.,* **190,** 190.

FRUIT NUTRITION

Soil moisture supply

A relatively dry season from the end of April until mid-September, when the maximum potential soil moisture deficit of 7·95 in. was reached, was opportunely broken by a partial replenishment of soil moisture reserves with 1·37 in. rain on 11th–12th June and a little over an inch of rain during the period 11th–16th July. Supplementary water was beneficial where applied.

Tree fruits.—The treatments started in 1953 on the Laxton's Superb apple trees on Plot L7 have now ceased and the eight years' data for growth and crop are being examined. The initial effect of ceasing irrigation, seen this season and undoubtedly enhanced by the dry summer, was very similar to the check to trees observed after grassing down.

The study of the interaction of nitrogen and water on growth and cropping of Laxton's Fortune apple trees, also on Plot L7, is being continued. The additive effect of water and nitrogen on growth has again been demonstrated but as these very lightly pruned trees were in the ' off ' year the effect on crop could not be assessed this season.

In the irrigation trial at Luddington Experimental Horticulture Station the growth of the Cox's Orange Pippin trees is related to the intensity of watering. Crops have again been light and growth of the watered trees very vigorous.

Small fruits.—The frost on 27th–28th May caused a considerable amount of damage to developing fruitlets of the Malling Jewel and Exploit raspberries in the mulch and irrigation trial. Damage appeared to be similar on all treatments. Yield increases due to mulching and irrigation were similar, amounting to 40% with Jewel and 14% with Exploit. A large part of this yield increase can be explained in terms of berry size for the mulched raspberries of both varieties and for the irrigated Exploit but not for the irrigated Jewel ; this is being investigated.

Amos Black black currants survived the late frost without apparent loss of crop. Yields were outstanding, averaging 9 to 10 tons per acre from unpruned irrigated bushes and 6·5 to 7 tons per acre from unpruned control bushes. Pruning, which was intended to remove one-third of the total wood and was actually found to have removed 39% of the new wood, reduced the crop by about 40% irrespective of water treatments even though it increased berry size by about 22%.

Mineral nutrition

Long-term manurial trials

The trees of Cox's Orange Pippin on M.XII in the manurial trial on Plot C2 did not suffer damage from the late frost and a good crop was produced. There was again a response to nitrogen in the cropping of the trees in the cultivated plots as well as those in grass. There was some evidence that the trees were suffering from a shortage of soil moisture, especially those in grass on the shallow soil, but this was not reflected in any marked reduction in fruit size.

In the pear manurial trial at Efford Experimental Horticulture Station, sponsored jointly with Long Ashton, the experimental trees of Conference were replaced with maiden trees of the same variety following the outbreak of silver leaf disease reported last year.

Nitrogen

Field trials.—The interaction of nitrogen treatments with soil moisture supply, and the response to nitrogen applications in the long-term manurial trial on apples, have been mentioned above.

In another field experiment on apples, being carried out at Efford Experimental Horticulture Station, three kinds of nitrogenous fertilizer are applied at different times through the year, on Cox's Orange Pippin trees under grass. The first year's treatments have been completed and no differences were seen.

In the experiment on magnesium-deficient Edward VII apple trees (see below), although two pre-blossom sprays of 0·5% urea annually did not prevent magnesium deficiency symptoms on the fruiting spur leaves, there has been a suggestion of an increase in fruit set in two of the three years so far. This is in accord with results from an experiment already reported (see Report for 1957, p. 18) in which five post-blossom sprays of urea were used. However, combined urea and magnesium pre-blossom sprays have shown no such effect.

Mineral nitrogen in soil.—Regular determinations of ammonium and nitrate nitrogen have continued on soil samples from the manurial trial on Plot C2. Very low levels were found from

October to February ; this was doubtless associated with the heavy rainfall. The seasonal pattern during spring and early summer was similar to that of the previous two years.

Evidence of leaching of available nitrogen from the soil by the heavy autumn rains was also obtained from the strawberry manurial trial. Although the second applications of nitrogen fertilizer in 1960 were made in August, the levels of inorganic nitrogen in the top 18 in. of soil were low by November and remained so until the spring fertilizer was applied.

These studies of trends of mineral nitrogen in soil have now been extended to the black currant and raspberry irrigation trials. Here the influence of soil moisture will be an additional factor on which information can be obtained, in relation both to downward movement of mineral nitrogen and to conditions for nitrification.

Determinations on samples from the soil management trial on Plot L8 have shown high levels of ammonium nitrogen in the soil of the very acid plots, indicating that nitrification has been impeded by these conditions.

Sand culture.—A sand culture experiment was started in September on the response of young apple trees to season of nitrogen supply. One group will be grown with a continuous moderate nitrogen supply ; the rest will receive low nitrogen either continuously or augmented for three months in spring, summer, or autumn with a high concentration of nitrogen.

To determine the nutrient solutions most suitable for the above experiment, growth of trees was observed in a series of solutions, ranging from 0·5 to 32 milli-equivalents NO_3/l. Under our conditions 4 m eq NO_3/l produced growth which would be considered adequate in the orchard and 8 m eq NO_3/l resulted in very vigorous growth. Up to 16 m eq NO_3/l both the growth and the concentration of nitrogen in the leaves increased with nitrate in the solution, but above this concentration there was no further increase.

A technique of automatic sub-irrigation was developed and used to grow 4-year-old trees of Cox on M.VII in sand culture. Some of the trees had received no nitrogen in the preceding year, with the result that blossoming in 1961 was reduced and delayed, fruit set was negligible, and leaf colour and size were poor. Trees which previously had nitrogen bore a small crop in 1961 ; the colour of the fruit was differentially affected by the four 1961 treatments, viz., adequate nitrogen, low nitrogen, and the latter combined with additional supplies in the spring or summer.

Magnesium

The study of the effects of pre- or post-blossom sprays of Epsom salt solution on magnesium-deficient dwarf pyramid apple trees of Edward VII on M.VII was continued for a third year. The control by pre-blossom sprays of early symptoms of magnesium deficiency on leaves of fruiting spurs was not accompanied by an increase in fruit set. This lack of effect on fruit set was also observed, as noted above, when urea was combined in the sprays with Epsom salt, even though pre-blossom sprays of urea alone tended to increase fruit set.

As in a previous experiment (see Report for 1959, p. 19), 5 post-blossom sprayings with 2% Epsom salt solution increased the retention of fruits without loss of fruit size ; a similar result was achieved with 3 post-blossom sprayings of a magnesium chloride solution containing half the equivalent amount of magnesium. The magnesium chloride sprays were almost as effective as the Epsom salt sprays in preventing foliar symptoms of magnesium deficiency from occurring on extension shoots both in this experiment and in a similar experiment on Crab C rootstock.

The trial of the effect of post-blossom sprayings of Epsom salt on growth and cropping of mature bush apple trees of three different varieties on M.II and M.VII was continued. The trial is in its second year and it is therefore too early to draw conclusions from it.

The trial with foliar applications of Epsom salt on a magnesium-deficient stoolbed of M.IV rootstocks was discontinued in 1960. Observations made that year showed a very small residual effect of the 3 Epsom salt spray applications made yearly for the past 7 years, both on the magnesium content of the leaves and on the intensity of foliar symptoms ; where 9 sprays were applied yearly, although the magnesium content of the leaves did not reach a ' normal ' level the residual effects were larger and the number and size of shoots was greater than on the control plots. By 1961, no differences in leaf symptoms due to previous treatments existed. Soil applications of Epsom salt continue to give little benefit to magnesium-deficient MM.102 rootstocks.

Trees were planted during the winter of 1960–61 for a trial on the effect of spray and/or soil applications of a magnesium compound on the growth and cropping of Cox's Orange Pippin and Worcester Pearmain on M.VII. Treatments will be started after five years, during which time the trees will be calibrated.

The results have been reported (U28) of a pot experiment carried out in collaboration with the Plant Protective Chemistry Section to investigate the effect of Epsom salt sprays on the incidence of

mildew on MM.102 rootstocks. Although such sprays gave some control of mildew, a further pot experiment indicated that mildew susceptibility is not directly related to the magnesium status of the plant (p. 91).

Uptake from foliar sprays

Work has continued on the uptake of magnesium from foliar applications of its salts ; the main interest has been in the chloride, which provides a wet deposit on the leaf surface under most conditions. However, it has not been found possible to isolate the factors which determine whether appreciable amounts of magnesium will, or will not, be taken up from a wet deposit on the leaf surface. A comparative study showed that the rate of uptake was invariably greater with the chloride than with an equimolar solution of the sulphate, and that over a period of a day or so a chloride solution of half strength would produce a total uptake at least as large as that achieved with the sulphate.

An alternative method of maintaining a wet deposit on the leaf surface is to use the deliquescent mixture which results when magnesium sulphate and urea are mixed in the correct proportions. Unfortunately no marked increase in rate of uptake (compared with magnesium sulphate) results from the use of such a mixture. In an effort to explain this anomalous result a series of experiments was carried out in which leaf surface deposits were determined at various times after treatment with urea, magnesium, or mixtures of the two. These results await detailed analysis.

A study of the uptake of iron from foliar applications of ferrous sulphate solution has been started. When a 0·01 M solution (about 0·3%) is applied to leaves of Worcester Pearmain uptake is rapid, and frequently the iron content of the leaf is increased by about 200 p.p.m. within an hour ; this represents about 25% of the applied iron. Usually the uptake ceases at this point, and is resumed overnight ; this is in agreement with expectation, for the surface deposit dries out, and is brought into solution again when the humidity rises overnight. However, on some occasions uptake continued on the day of application after it might have been expected that the surface deposit would have dried out.

Mixtures of ferrous sulphate and magnesium sulphate or magnesium chloride have also been used. Magnesium sulphate has very little effect on the uptake of iron but magnesium chloride, which maintains a wet deposit on the leaf surface, increases the rate of uptake. This result, however, is of theoretical interest only, for the latter mixture may damage leaves.

Leaf samples have again been collected from the trials on Edward VII and Crab C, mentioned above, so that the effects of foliar sprays of magnesium sulphate or magnesium chloride on the mineral composition of treated leaves can be determined.

Routine Analysis Unit

About 3,000 samples of plant material have been analysed during the year, mostly for nitrogen, phosphorus, potassium, calcium, and magnesium. A number of determinations of iron and manganese have also been carried out, and the amount of copper deposit on a series of leaf samples has been determined. Samples of fruit from storage experiments have been analysed.

The Unit has also determined nitrate and ammonium nitrogen on 700 soil samples in connexion with the studies mentioned above on the seasonal trends of mineral nitrogen in orchard soils ; samples of nutrient solutions have been analysed.

A rapid flame photometric method for calcium estimation has been found to give satisfactory agreement with results obtained by the more lengthy EDTA titration procedure, and has recently been introduced for routine analysis.

Soil management trials

In the soil management trial on the light soil at Larkfield (Plot LS), the repeated use of sulphate of ammonia has produced very acid soil conditions, believed to be responsible for the ' dieback ' of one-year shoots observed in some seasons and for recent failures of attempts to establish annual cover crops. To correct this acidity, ground chalk has been applied at the rate of 2 tons per acre.

Two more plots have been grassed down in the pilot trial on cherries, completing the series of six different times of grassing down which started two years after planting. Because the crops have been small, no assessment of the effects of treatments on cropping has so far been possible.

A study is being made of the suitability of several Mediterranean strains of Tall Fescue (*Festuca arundinacea*) for use in orchard swards. In trials at the Grassland Research Institute, Hurley, it was found that these strains make most of their growth during the winter months. Observations on their effect on soil conditions, particularly on soil moisture during the spring and summer, should indicate whether or not they will offer less competition with fruit trees than the types of grass now used in

orchards. Larger plots will also be sown to provide an opportunity for assessing the performance of strains of Tall Fescue under orchard conditions.

Soil variation at East Malling

The soil samples obtained in the pH survey (U27) have been used to make up bulked samples of various areas, for analysis by the N.A.A.S. ; these will provide systematic information on the status of available phosphate, potash, and magnesium from 0–6 in. and 6–12 in. depths on all the Research Station land.

In collaboration with the Statistics Section (p. 15) further papers have been prepared on the history of the Research Station land (p. 85) and on the progress of the trial on the restoration of uniformity of old orchard land.

Publications during the year

U27 White, G. C. (1961). **A survey of the pH of the soils of East Malling Research Station.** *Rep. E. Malling Res. Sta. for 1960,* 77-80.

U28 Ford, Elsie M., and Frick, E. L. (1961). **The effect of Epsom salt on the incidence of powdery mildew on potted apple rootstocks.** *Rep. E. Malling Res. Sta. for 1960,* 81-4.

PLANT PATHOLOGY

BACTERIAL DISEASES

Fire-blight of pear *(Erwinia amylovora)*

Studies on the physiology and biochemical characteristics of *Erwinia amylovora* have been completed, and further work on fire-blight is now in abeyance.

Bacterial canker of stone-fruits *(Pseudomonas mors-prunorum)*

In the modified field trial (Report for 1960, p.24) all autumn sprays again reduced canker infections and Bordeaux mixture was superior to copper oxychloride. There was some evidence of additional control from spring sprays which cannot at present be related to the amount of inoculum available for infection during the autumn.

In collaboration with the Plant Protective Chemistry Section a search was begun amongst quaternary ammonium compounds and other bactericides for a material to replace Bordeaux mixture. Four compounds showing promise in laboratory tests have been selected for preliminary field comparisons with Bordeaux mixture. The sprays were applied in July and their effectiveness determined by estimating bacterial populations in rain-water draining down the trees. None of the test compounds was as active or as persistent as Bordeaux mixture. Some caused a slight temporary reduction in the populations of *Ps. mors-prunorum*, while others apparently altered the micro-flora of the tree surfaces.

The collaborative experiments with the Pomology Section on the selection of cherry and plum rootstocks resistant to bacterial canker were continued. After reinoculation, about two-thirds of the 400 cherry mazzard seedlings surviving from last year's experiment were discarded and a quarter of the remainder were noted as being very highly resistant. The 67 clones of seedling St. Julien of Orleans plums were also reinoculated and it was confirmed that 24 of them were very highly resistant or immune to the disease. In a replicated field trial of plum rootstocks worked with the scion varieties Victoria and Early Laxton, the rootstocks Myrobalan B, Belgian Myrobalan and EA16 were more resistant than Brompton, St. Julien A and EC3. There was a significant interaction between scion and rootstocks, those worked with Victoria developing larger cankers than those worked with Early Laxton.

Further experiments on the growth of *Ps. mors-prunorum* in plant tissues have confirmed that no multiplication takes place within apple leaves. Similarly no growth was observed in pear leaves, although the related pathogen, *Ps. syringae*, multiplied slowly. In plum and cherry leaves the rate of growth of *Ps. mors-prunorum* followed a logarithmic course and maximum populations were reached after 4–5 days.

Investigations of the disease cycle on plum again showed stem tissues to be most susceptible in December. Evidence from inoculation experiments suggests that cankers in the field probably originate from the infection of the cortex through very small wounds. The rate of canker extension was at a maximum during the blossom period, but thereafter it declined gradually and ceased altogether by the end of May. The numbers of *Ps. mors-prunorum* in rain-water draining from plum trees followed the same pattern as last year. Thus the pathogen was not detected during the dormant period but it appeared in large numbers as soon as the buds burst. Evidence is accumulating which suggests that the pathogen can survive the winter as a saprophyte in dormant buds.

Bacteriophages

Over 50 phages isolated from soils, using *Ps. mors-prunorum*, *Ps. syringae* and other plant pathogens as propagating hosts, have been systematically tested against a wide range of *Pseudomonas* spp. including several found in soil and water. Phage sensitivity in the genus *Pseudomonas* was found to be extremely complex and the phages were unable to distinguish between plant pathogens and saprophytes.

Plum and cherry strains of *Ps. mors-prunorum* were indistinguishable by routine biochemical tests but they differed in phage type. Since plum and cherry strains show some degree of pathogenic adaptation to their original host this suggests a relationship between phage type and specific virulence factors in *Ps. mors-prunorum*. Isolates of *Ps. mors-prunorum* were identical in their biochemical behaviour and distinct from *Ps. syringae*, but a few plum isolates of *Ps. mors-prunorum* were indistinguishable from pear isolates of *Ps. syringae* by phage typing. Lack of correlation between biochemical activity and phage sensitivity was also observed amongst other isolates.

The existence of *lysogenic strains* of *Ps. mors-prunorum*, i.e. those carrying latent phage material which is propagated indefinitely with the host cell, has been demonstrated ; they appear to be fairly common. About half the cherry strains and a fifth of the plum strains examined were lysogenic but the phenomenon is much rarer in *Ps. syringae*. Several lysogenic phages have been isolated and studies of their host range and specificity are in progress.

FUNGAL DISEASES

Apple and pear scab *(Venturia spp.)*

Host parasite relationships

Reisolation of clones of *V. inaequalis* from artificially inoculated Cox leaves is in progress, and new isolates of the pathogen from the varieties Edward VII, Miller's Seedling, Charles Ross and Early Victoria have been added to the collection.

The antisporulant activities of standard Krebs cycle inhibitors have been investigated further. These inhibitors and *o*-coumarate were added to the cultures at the end of the lag phase of growth to avoid effects on spore germination. As expected, the non-competitive inhibitors were more active than the competitive inhibitors ; they also restricted growth, fluoroacetate being the most active compound tested. *O*-coumarate was similar to the non-competitive inhibitors in antisporulant activity but, while not inhibiting growth, it induced colour changes in the mycelium suggesting an altered metabolism.

In collaboration with the Biochemistry Section further studies have been made of acid profiles resulting from treatment with standard inhibitors and *o*-coumarate. It was found that the complex natural media required for optimal growth of *V. inaequalis* contain organic acids. The cultures were therefore washed aseptically towards the end of the lag phase of growth, and the media replaced with solutions of glucose and inorganic salts containing the inhibitors. *O*-coumarate caused a slight increase in the production of pyruvate but, in contrast to arsenite, no increase in ketoglutarate. The resulting acid profile was dissimilar to that produced by malonate but neither profile differed strikingly from the control.

A series of esters of *o*-coumaric acid, prepared by the Plant Protective Chemistry Section, are being tested as eradicant fungicides under glasshouse conditions. The *n*-propyl and *n*-butyl esters were more active than the acid as inhibitors of clone E1 of *V. inaequalis*.

Epidemiological studies

This year the surface-wetness recorder was sited on the Meteorological Plot as standard equipment, and the interpretation of apple-scab infection periods slightly modified in accordance with N.A.A.S. methods. Only three infection periods were recorded between the beginning of April and the end of ascospore discharge, fewer than in any season since 1958 when observations began (see Field Trials).

Ascospores were detected in a Bramley orchard at the end of March and for about six weeks thereafter. No ascospores appeared in the spore traps after 6th May, but airborne conidia were detected later in the season.

Exploratory experiments on the use of post-harvest sprays to prevent ascospore maturation were continued. Leaves were treated with various compounds in the autumn and spore productivity estimated in wind tunnels the following spring. Ascospore production was again completely suppressed by 0·1% PMC but not by dichlorophen, Bordeaux mixture, and copper, ammonium and ferrous sulphates. Perithecia-like structures containing conidia, in leaves treated with 0·1% PMC, were not observed this year and no conidia were released in the wind tunnels.

Evidence that the number of ascospores released in the spring is related to the amount of late season infection the previous year was not confirmed in 1961, the ascospore ' catch ' being substantially less than was expected from the heavy late season infection in 1960.

Glasshouse studies on MM.109 rootstocks were chiefly concerned with investigating methods of inoculation with ascospores and with the influence on infection of alternate wet and dry periods. Drifting spores were not satisfactorily impacted at low air speeds, but heavy infection followed gravity impaction of spores from dead leaves suspended above the test plants. Preventing evaporation of the infection drop by maintaining high humidity proved more successful than frequently rewetting leaves from automatic nozzles at lower humidity. Comparisons of different periods of leaf wetness revealed an optimum period beyond which the rate of infection decreased. Infection also decreased if intervening dry periods were extended beyond a few hours.

The experiments indicate that infection can take place under many variations of the usual field

interpretation of ' Mills Periods ' ; in practice, however, these variations may be of only limited local importance, and the criteria at present used for determining infection periods seem satisfactory.

Field trials

In the dry 1961 season there were few infection periods at East Malling and on Cox's Orange Pippin curative (post-infection) spraying compared more favourably with protective spraying than in 1960 (see Report for 1960, p. 26). Good control of moderate scab infection from eight protective lime-sulphur sprays was matched by three dodine acetate sprays applied curatively.

Apple mildew *(Podosphaera leucotricha)*

The results obtained in the past three years on the effects of oil-emulsion sprays in controlling primary mildew infections in buds have been summarized (p. 97) and their bearing on the whole problem of apple mildew control is discussed in a bulletin (p. 122). On Cox's Orange Pippin, dormant sprays of PMC and dichlorophen had no action on the perennating mycelium. In a spray trial on a low hedge of M.III rootstocks, in collaboration with the Plant Protective Chemistry Section, five applications of 1% lime-sulphur or of 0·025% dinocap (Karathane) as a wettable powder, gave better control than five of 0·019% or of 0·013% dinocap ; the last proved unsatisfactory when applied at 10–14 day intervals even with added wetter. In a similar trial, spray concentrates of dinocap and of an equivalent amount of the corresponding free phenol were less effective than comparable high volume sprays. A laboratory formulation of dinocap was more effective than a commercial wettable powder of equivalent content (0·019%). Preliminary results with a summer-pruning technique, developed to facilitate studies of the infection requirements of mildew conidia (see Report for 1960, p. 26), are encouraging. Observations so far indicate that new mildew infections take place almost every day and as late as mid-September. Infection occurred over a wide range of temperatures with the optimum in the region of 20° C. During periods of appreciable rainfall the numbers of new infections were reduced.

Gloeosporium diseases *(G. album and G. perennans)*

Spores of *G. album* were released throughout the season in an orchard of Cox's Orange Pippin and reached a maximum in early July. Investigations aimed at reducing fruit rots by suppressing sporulation of the fungi in the orchard are now in progress. Spring sprays of 0·1% PMC applied before bud-burst in 1960 suppressed spore production during early summer, but spore numbers increased during August and by autumn exceeded those from the unsprayed trees. From July to September, however, the critical period for fruit infections, the total spore production on the treated trees was substantially reduced and this was reflected in the amounts of storage rots recorded early in 1961, i.e. 5% compared with 21% on the fruit from the unsprayed control trees.

Autumn (post-harvest) applications of 0·1% PMC suppressed sporulation initially but by the following summer the effect of the spray had almost disappeared.

A field trial was begun to assess the value of summer eradicant sprays, applied whenever the spore-traps indicated an increase in spore numbers. Three sprays of dichlorophen during 1961 summer were sufficient to restrict the build-up of inoculum, but their effect on fruit rot will not be known until early in 1962.

A greenhouse technique has been devised to test the antisporulant properties of fungicides as alternatives to PMC. Stubs on trees of Cox's Orange Pippin in pots were inoculated with *G. perennans* and sprayed with the test material when sporing lesions were established. After treatment spore productivity was determined by washing the stubs at weekly intervals and counting the numbers of spores in the washings. Several materials show promise as antisporulants including the propyl ester of *o*-coumaric acid and coumarin, formulated in linseed oil and octanol.

A similar greenhouse method is being used to compare the pattern of spore production in *G. album* and *G. perennans*. The object is to see how far data on the sporulation of *G. album* in the field are applicable to *G. perennans*, the spores of which cannot yet be distinguished from those of other fungi. Attempts to facilitate identification of *G. perennans* spores by combining a fluorescent dye with a specific antiserum (see Report for 1960, p. 27) have so far been unsuccessful.

Investigations on the perfect stages of *Gloeosporium* spp. are continuing. Observations suggest that this stage is not often formed on stub and die-back infections within the orchard.

In collaboration with the Fruit Storage Investigations team fruit from 12 commercial orchards, each receiving differential nitrogen treatments, were loaded with spores to determine their susceptibility to *G. perennans*. Fruit from trees receiving extra nitrogen was most susceptible, but there was no evidence that susceptibility was related to any other mineral constituent of the fruit.

Apple canker *(Nectria galligena)*

A comparison of mercury and copper preparations for control of canker was partly vitiated by a high casualty rate amongst the M.VIII rootstocks from infection near ground level. Nevertheless, there were indications that both materials were equally suitable for control.

A bud-rot disease of hazel *(Gloeosporium spp.)*

Inoculation experiments have elucidated further aspects of the disease cycle and a full account of this disease is in preparation.

Strawberry fruit rot *(Botrytis cinerea)*

A routine schedule of four normal-strength thiram sprays starting at full bloom was compared with a schedule of two sprays, the first at normal strength in bloom and the second at three times normal strength when the berries were half grown. Both schedules reduced fruit rotting to negligible proportions, but only light infection developed on unsprayed plants in the dry 1961 season.

Silver leaf disease *(Stereum purpureum)*

The trial to determine the effects of removing silvered branches from mature trees infected with *S. purpureum* was continued. Several branches were cut off during 1961 and it was noted that the fungus had already progressed into the trunk.

Injection of *o*-coumaric acid or its sodium salt had no effect on the development of *S. purpureum* in young plum trees. Bark applications of 2,3,5,6-tetrachlorobenzoic acid were also ineffective and marked phytotoxicity symptoms developed at the point of application and in the shoots.

Hop verticillium wilt *(V. albo-atrum and V. dahliae)*

Farm trials of new varieties

Observations continued for the second year in the farm trials of the varieties W/E 66, W/E 1008, and W/E 1778, derived from the Wye/East Malling breeding projects. Maximum wilt incidences of 1%, 3% and 5% respectively were recorded. These values, comparable with those of the previous year, all occurred on the same farm, where 6·5% wilt was recorded in the ' control ' plot of Whitbread's Golding variety.

Tolerance testing of new varieties

Thirty-three varieties were tested at the 30-plant level : these included one from the 1950 project, which was comparable in tolerance with OR/55 ; the remainder were mainly derived from the current Wye breeding projects and exhibited the whole range of tolerance levels. Five varieties were tested at the 5-plant level.

The possibility of using rooted cuttings for tolerance tests is under investigation. In a calibration experiment under glass, varieties of differing tolerance behaved as expected, but in a similar trial outside one variety gave anomalous results. A preliminary attempt was made to test the tolerance of five seedling families by repeated massive conidial inoculations applied to the soil when the seedlings were just past the cotyledon stage. It was hoped to achieve rapid killing of the sensitive seedlings by this means, but this did not occur.

Severe wilt in tolerant varieties

Observations continued at a number of sites at which severe wilt in tolerants had been recorded since 1958. At two of these the level of wilt was considerably less than in the previous year ; at the others fairly high levels were maintained.

Environmental effects on wilt incidence

Renewed efforts have been made to correlate seasonal fluctuations in wilt incidence in tolerant varieties with weather conditions. Evidence is accumulating that soil temperature may be of greater significance than soil moisture during the early stages of disease development.

Fluctuating wilt in tolerant varieties

Two experimental varieties (W/E 752 and W/E 1669) known to be highly tolerant of progressive wilt were inoculated with an isolate of *V. albo-atrum* from a West Midland fluctuating wilt outbreak. The plants developed slight symptoms, but all were infected, and the fungus was isolated from the bines. Tylosis of the vascular system was invariably associated with infection in exactly the same way as has previously been reported in less tolerant varieties.

Studies in host-parasite relationships

Resistance mechanisms in hops.—In studies on the development of the endodermis in non-infected roots of a range of sensitive, moderately tolerant and highly tolerant varieties, increasing tolerance appeared to be associated with progressively earlier completion of endodermal suberization.

The presence of suberin in the hypodermis of Bullion has now been established.

Resistance mechanisms in other species.—Crop plants investigated in 1961 included mangold, fodder-beet, lucerne, turnip, cabbage, pea, wheat, oats and barley. Examination of the inoculated material is still in progress, but vascular infection has been confirmed in lucerne, turnip and cabbage. In all of these the spread of the pathogen in the vascular system appears to have been limited by intense gumming.

Phenolic substances in the host-parasite relationship.—There is accumulating evidence that the intensity of cortical defence reaction, viz. cell wall thickening, and lignituber formation, is related to the phenolic content of the tissue, as indicated by the Hoepfner-Vorsatz reaction. It has also been shown that the fungus is capable of oxidizing a number of phenolic substances, and that it also produces a β-glycosidase capable of splitting phenolic glycosides such as arbutin and phloridzin.

The 'black strip' symptom in progressive wilt.—A common feature of the lower parts of severely 'wilted' bines is the presence of six longitudinal black strips. This, previously attributed to the presence of carbonized masses of mycelium after invasion of the cortex outside the main vascular bundles, has now been shown to be the result of delayed cork formation over the six collenchyma bands in the outer cortex. Because of this the underlying cortical tissues are relatively exposed, and the blackening associated with oxidation of phenolic materials as the bine dies is evident. The pathogen is often present throughout the cortex at this stage.

Disposal of hop residues from infected gardens after machine picking

Following the demonstration of the infectivity of machine-picked hop waste (Report for 1960, p. 100), the effect of composting on the infectivity of infested waste has been studied in collaboration with the Department of Hop Research, Wye College. Hop waste infected with *Verticillium* was buried at various positions in a well insulated compost heap. Temperatures in the heap were recorded at intervals throughout the 5-month period of composting : temperatures lethal to *V. albo-atrum* were reached at most of the positions where waste was buried. After recovery, the infectivity of the composted waste samples was tested in a field experiment using Fuggle N plants as indicators. No infections resulted from samples which had been buried in the heap, but one sample from the surface was still infective.

Pathogenicity tests

During the winter and early spring a number of *V. albo-atrum* isolates from West Midland farms were successfully tested in the glasshouse, using rooted shoots of hop. Most of these proved to be of mild pathogenicity but a few produced wilt symptoms comparable in severity to a progressive strain used as a control.

Studies in the soil relationships of *Verticillium albo-atrum*

Survival in the soil.—After four years of grass cover no *V. albo-atrum* was recovered from land which had previously carried a severely wilted crop of hops, but the fungus persisted in plots under annual weed cover. A farm that was severely infected is now largely free of *V. albo-atrum* after five years of grass cover. There are still small pockets of infection, however, suggesting that inoculum may persist deep in the soil. Two new field trials were laid down in a commercial hop garden to study further the effects of grass cover on the survival of *Verticillium*.

Verticillium wilt of strawberry (*V. dahliae*)

The second year of a tolerance trial showed that the progress of the disease from year to year is by no means consistent throughout the range of nine varieties ; Cambridge Vigour and Rearguard maintained high and moderately high disease ratings respectively ; Cambridge Favourite, Merton Princess, Talisman, Premier and Royal Sovereign maintained low ratings ; Mme. Lefèbvre showed a marked increase of disease, while in Huxley there was a considerable reduction. The disease was prevalent in certain runner beds and many runners infected from the mother plant via the stolon were killed.

Verticillium in quince rootstocks (*V. dahliae*)

The tolerance trial of five quince rootstocks under Conference pear ended after three years in which no symptoms directly attributable to *Verticillium* had been recorded despite soil inoculation in

the early summer of 1958 and again in the autumn of 1959. Examination of the trunk bases showed that rather minor infections had occurred in some trees, but the incidence and intensity of vascular staining were so low as to make comparisons between clones unsatisfactory. A small but consistent difference was apparent in extension growth between inoculated and non-inoculated trees ; analysis of these data is still in progress. Marked dwarfing of both inoculated and non-inoculated trees on two of the rootstocks appeared to be the result of incompatibility.

FUNGICIDE INVESTIGATIONS

Concentrate sprays

Glasshouse experiments on MM.109 rootstocks were continued to determine optimum droplet-size for control of apple scab with neat lime-sulphur. An improved spinning-disc apparatus was constructed in collaboration with the National Institute of Agricultural Engineering. In several experiments infection of the controls was unexpectedly low and the possibility that this may be due to redistribution of the fungicide at high temperatures is under investigation.

In a field trial to test concentrates of organic fungicides, dodine acetate was superior to captan or thiram against scab on Cox's Orange Pippin, but caused more fruit russet. Dinocap was used in each case for mildew control. One pre-blossom and two post-blossom applications of lime-sulphur or colloidal sulphur concentrate at 2-3 week intervals proved inadequate against heavy scab infection on Bramley's seedling pyramids.

On Williams' and Comice pear pyramids captan concentrate was preferable to lime-sulphur or colloidal sulphur concentrate on account of phytotoxicity. No significant differences were observed between high volume, medium volume and concentrate sprays of captan, although infection was least on the high volume plots.

VIRUS DISEASES OF FRUIT TREES

Apple

Transmission tests from stunted Worcester trees that were rubbery and had swellings on the trunks and branches showed that they were infected with rubbery wood and flat limb viruses.

Graft inoculations from a wide range of apple varieties and rootstocks to apple indicator plants and peach seedlings strongly suggest that the dark green mottle symptoms on peach are caused by apple stem pitting virus.

Some of the widely distributed ' latent ' viruses in apples, such as chlorotic leaf spot virus, had severe and sometimes lethal effects on several varieties of ornamental crab apples.

Pear

Cross transmissions between apple and pear showed that some viruses infect both of these crops. Apple rubbery wood virus was transmitted from several pear varieties to Lord Lambourne apple : Beurré Hardy pear trees inoculated with chlorotic leaf spot virus from apple developed ring and line patterns on the leaves.

In a field trial of the effect of pear viruses on growth and cropping, some common viruses such as vein yellows reduced the growth of 4-year-old trees by nearly 50%.

Cherry

Cherry leaf roll, arabis mosaic and raspberry ringspot viruses were detected in crude cherry sap from infected trees by serological tests. The tests, though reasonably reliable during early spring, were unsuccessful after mid-May. Although serological tests have been very useful in identifying viruses transmitted from cherry trees to herbaceous hosts, they are not yet generally applicable for testing cherry trees for virus infection.

Budwood was collected for virus tests on 140 cherry Mother Trees that nurserymen had obtained from the Research Station between 1953 and 1955.

Plum

In the trial of the effect of virus on the growth and cropping of four plum varieties, one of the five viruses under test, prune dwarf, has severely checked growth in Oullins Golden Gage and has affected Marjorie's Seedling, Victoria and Cambridge Gage to a lesser extent. This same virus also markedly

reduced crop weight in Victoria and Marjorie's Seedling. Frost damage prevented cropping of the other two varieties.

VIRUS DISEASES OF SOFT FRUITS

Strawberry

Work with strawberry green petal and other indigenous leafhopper transmitted viruses of the yellows group has been mainly concerned with host and vector relationships.

Repeated attempts to infect the annual aster (*Callistephus chinensis*) using *Aphrodes bicinctus* and *Euscelis plebejus* as vectors, were unsuccessful and no transmissions were obtained with *Cuscuta* spp. In similar experiments the number of successful infections in celery and carrot seedlings was extremely low. These results emphasize the differences between the viruses present in this country and European and American aster yellows.

The leafhopper *Aphrodes bicinctus* was able to transmit clover phyllody but not witches' broom. There is evidence that *Euscelis plebejus* will not transmit phyllody if it is already infected with witches' broom ; one possible explanation of this, namely virus cross-protection within the vector, is under investigation.

Loganberry and blackberry

Rubus stunt virus has been transmitted from diseased to healthy loganberry plants by *Macropsis fusculi* Zett. and from diseased to healthy blackberry by *M. scotti* Edwards.

Experiments on sudden wilt disease in Himalaya Giant blackberries suggest that it is caused by a virus transmitted by a leafhopper.

Currants and gooseberries

The symptoms of black currant vein pattern virus, previously known only from a single locality in Kent (Report for 1951, p. 133), have been found at several other plantations in the county. In each instance affected bushes also showed the early symptoms of reversion. The vein pattern virus was transmitted readily by black currant gall mites (*Phytoptus ribis* Nal.) from several sources. Infested plants have not shown reversion symptoms, perhaps because foliage symptoms are masked under glasshouse conditions.

A common leaf malformation, often ascribed to the effect of reversion virus, has been shown to be caused by gall mites in the apical meristems of affected shoots. Since this malformation is independent of that caused by reversion virus, it provides an easy method of estimating the incidence of mites during the growing season, when big buds are not obvious.

VIRUS DISEASES OF HOP

Nettlehead

Nettlehead was transmitted from hop to hop by sap inoculation, but not from hop to a range of 28 other herbaceous species. Attempts to improve the rate of transmission by concentrating the extract have not succeeded. Experiments are in progress to find whether nettlehead is spread in the field by contact between diseased and healthy plants. In the field trial designed to assess the relative importance of soil and air-borne infection in nettlehead disease, 19 plants, all with roots exposed to the soil, have developed line pattern symptoms. Studies of nematode populations in hop plantations have been continued in collaboration with the Entomology Section.

Line pattern

Humulus americanus var. *neomexicanus* has been found to be a sensitive indicator for the virus causing line pattern in hop, and has been used to demonstrate the presence of this virus in an isolate of split leaf blotch having a severe effect on plants of Keyworth's Midseason and College Cluster. The virus was not detected in three other sources of split leaf blotch, but was present in a plant showing nettlehead symptoms.

Split leaf blotch virus

Fuggle seedlings have proved unreliable as test plants for this virus, but two cuttings from a heat treated clone of Fuggle N show promise of being superior to the existing indicator clone. Sap inocula-

tions from infector hops to healthy hops and various herbaceous plants have so far given negative results.

Mosaic

Mosaic virus was successfully transmitted from Fuggle to Early Prolific and Bramling hop plants by sap inoculation. In experiments involving large numbers of winged *Phorodon humuli*, three plants of a sensitive variety were infected from a Fuggle carrier.

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C465 TALBOYS, P. W., BENNETT, MARGERY, and WILSON, J. F. (1961). **Tolerance to *Verticillium* wilt diseases in the strawberry.** *Rep. E. Malling Res. Sta. for 1960*, 94-9.

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C469 HARRIS, R. V. (1961). **Progress in research on *Verticillium* wilt and virus diseases of hops in 1960.** *Rep. E. Malling Res. Sta. for 1960*, 141-4.

C470 MOORE, M. H. (1961). **Controlling strawberry *Botrytis*.** *Rep. E. Malling Res. Sta. for 1960*, 132-3.

C471 — —— (1961). **Concentrate spraying of apple trees. II. Dosage/volume relationships of lime-sulphur in disease control and spray damage.** *Ann. appl. Biol.*, **49**, 254-66.

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ENTOMOLOGY

Biology and chemical control of fruit pests

Codling moth, *Cydia pomonella* (L.)

The presence of empty pupal cases indicated that emergence began on 26th May, 11 days before any moths were caught in a mercury vapour light trap situated in the same orchard. During this period dusk temperatures were near or below the threshold for flight (50° F) and activity was probably minimal.

Field trials have again been mainly concerned with variations in concentration and time of application, using lead arsenate as the most selective chemical at present available for an integrated spray programme, and azinphos-methyl as a representative of the ' broad-spectrum ' contact insecticides. Due to the use of single tree plots the results refer only to control of first generation larvae.

Lead arsenate at 0·2%, applied high volume in mid-June and early July, reduced the infestation by 34% compared with 51% for sprays applied in late June and mid-July. In another trial the addition of a petal-fall spray to the latter schedule improved control from 57% to 93% and thus confirmed the value of this early application. Three sprays at fortnightly intervals from mid-June gave 80% control. Residues on the fruit at harvest were determined by the Plant Protective Chemistry Section.

Applications, in mid-June and early July, of azinphos-methyl at 0·04%, 0·02% and 0·01% reduced the infestation by 97%, 89% and 87% respectively ; an additional spray, in late July, to the 0·04% schedule resulted in 100% control. Three sprays of 0·02%, at fortnightly intervals from mid-June, gave 99% control.

Fruit tree tortrix moths

Light trap captures were obtained from Eastry, Kent, and Wisborough Green, Sussex, for a comparison of flight periods in different areas. Adults of the fruitlet mining tortrix, *Pammene rhediella* (Clerck) were noted in flight during the apple blossom period.

Fruit tree red spider mite, *Metatetranychus ulmi* (Koch)

Orchard studies have shown that the hatching period of winter eggs can differ, in the same area, by as much as four weeks. As a guide to the timing of sprays, the development of the first generation was followed in a ' normal ' population, i.e. one in which hatch began at the pink-bud stage.

In the trial at the Essex Institute of Agriculture, control has been satisfactory for the third year with dimethoate, phenkapton, 2,4,5,4'-tetrachlorodiphenyl sulphone and 2,2,2-trichloro-1,1-bis (4-chlorophenyl)ethanol when used either as repeated treatments of a single chemical or when an organophosphorus compound was alternated annually with one of contrasting chemical structure.

In a small-scale trial, with two applications of each material, poor control was obtained with 0·05% dinoseb dimethylacrylate and 2·25% of one of the less viscous polybutenes ; 0·03% 2,2,2-trichloro-1,1-bis(4-chlorophenyl)ethanol (more effective as an emulsifiable concentrate than as a wettable powder) was about equal in performance to 0·05% quinoxalinyl-2,3-trithiocarbonate, whilst 0·05% ethion gave still better control, at least equal to that obtained by 0·02% phenkapton. As in 1960, russeting and cracking of Cox's Orange Pippin fruits resulted from high volume sprays of 2,2,2-trichloro-1,1-bis(4-chlorophenyl)ethanol at petal-fall but not when applications were made two weeks later. Both the emulsifiable concentrate and the wettable powder caused symptoms of equal severity but a much smaller proportion of the crop was damaged by the latter. Injury originated where large drops of spray collected between fruitlets, so lower volume applications may prove safer.

Bryobia mites

Biological studies have continued.

Black currant gall mite, *Phytoptus ribis* Nal.

Neither quinoxalinyl-2,3-trithiocarbonate, when used in 1960, nor 20 additional chemicals applied as foliar sprays in 1961, have shown any signs of marked biological activity against the mite ; five systemics applied as soil drenches also gave disappointing results.

Raspberry beetle, *Byturus tomentosus* (Deg.)

Rather belated laboratory tests have shown that 0·05% malathion possesses a strong ovicidal action which, in combination with the proven toxicity to adults and larvae, should permit adequate control on loganberry from a single application. The inclusion, in previous trials, of unsprayed plots from which reinfestation occurred has prevented full assessment of this aspect.

Strawberry seed beetle, *Harpalus rufipes* (Deg.)

In tests, conducted by other research associations, no effect on flavour has been detected in processed fruits from plots treated with aldrin at 5 lb/ac immediately before strawing.

Laboratory studies of chemicals

Rearing test insects and mites

Cultures of codling moth, the coccinellid (*Propylea 14-punctata* (L.)), *Drosophila melanogaster* Meig., the mottled arum aphid (*Aulacorthum circumflexum* (Buckt.)), and a non-resistant strain of the fruit tree red spider mite have been maintained. A culture of the summer fruit tortrix moth, *Adoxophyes orana* (F.R.), has been re-established.

Malus hupehensis (Pamp.) and *M. fusca* (Raf.) have not proved to be very satisfactory hosts for the fruit tree red spider mite, since any advantage conferred by reduced susceptibility to apple mildew has been more than offset by the failure to maintain such thriving cultures of mites as on seedlings of commercial varieties.

Collaborative studies with the Plant Protective Chemistry Section on the residual toxicity, to day-old codling moth larvae, of naturally weathered deposits have continued. Several new chemicals have been tested, and comparisons also made between differing concentrations of azinphos-methyl, DDT and *O*-1-naphthyl *N*-methylcarbamate when applied as single or repeated applications. The results lead to the general conclusion, which receives support from the field trials mentioned earlier, that three sprays at half strength at fortnightly intervals should give more effective control than two sprays of standard strength at three-weekly intervals.

Other studies with codling moth have concerned ovicidal action, in which 100% mortality of both early and late stage eggs has been obtained only with organophosphorus compounds, and the dosage-mortality relationship of fresh deposits to young larvae. The latter information now opens up the possibility of predicting the performance of the chemicals tested on the basis of data obtained from analysis of deposits on the fruit.

The fungicides captan, dinocap and dispersible sulphur were practically non-toxic to nymphs of *Blepharidopterus angulatus* (Fall.) and *Psallus ambiguus* (Fall.) whilst lime-sulphur, in both dilute and concentrate form, caused considerable mortality (see p. 109). Other tests showed that fresh deposits of 1,1-dichloro-2,2-bis(4-chlorophenyl)ethane and DDT were of similar toxicity to nymphs of *B. angulatus*.

In experiments with *M. ulmi* at 55° F and 75° F there was no evidence that temperature influenced the toxicity of 2,2,2-trichloro-1,1-bis(4-chlorophenyl)ethanol to either summer eggs or adults.

Integration of chemical and natural control

The trial investigating the effects of γ-BHC/DDT and lead arsenate/nicotine at the green cluster stage has continued for a third year. Populations of *M. ulmi* and *Bryobia rubrioculus* Scheut. are now highest on the BHC/DDT plots.

An orchard trial to assess the effect, on *B. angulatus*, of full programmes of captan, captan/dinocap, lime-sulphur and lime-sulphur/dispersible sulphur gave inconclusive results due to low populations of the predator. There were, however, indications that predators were reduced by lime-sulphur and, to a lesser extent, by dinocap, the latter effect being at variance with laboratory results. No differences were detected due to the inclusion of either nicotine or γ-BHC in the petal-fall spray.

An observation plot has been established to study effects on pests and predator populations resulting from a full spray programme containing colloidal sulphur, lead arsenate and nicotine.

Host resistance

(In collaboration with the Pomology Section.)

Two families of apple seedlings, with Northern Spy as one parent, have been tested against woolly aphid, *Eriosoma lanigerum* (Hsmnn.), to provide data for genetic analysis and material for histological studies.

Cultures of strains 2-4 of the rubus aphid, *Amphorophora rubi* (Kalt.) have been maintained and tests of raspberry seedlings for resistance have continued.

A method has been developed for inoculating black currant seedlings with the gall mite, *Phytoptus*

ribis; this technique will be used in the initial assessment of resistance in hybrid families. No mites could be found on gooseberry seedlings a week after transfer ; on red currants some survived in the leaf axils and apical buds for periods up to two weeks, their presence being associated with necrotic areas between the bud scales and slight leaf distortion at the growing tip of the variety, Fay's Prolific.

Vectors of virus diseases

Leafhoppers

Field observations on the life cycle of *Aphrodes bicinctus* (Schrank) have continued, as have the trials in which the incidence of rubus stunt is being followed in relation to chemical control of the vector, *Macropsis scotti* Edwards.

Nematodes

Surveys of the distribution of potential virus vectors, chiefly of the genera *Xiphinema* and *Longidorus*, have continued in collaboration with the Plant Pathology Section. There is no evidence of a strong correlation between the occurrence of these nematodes and the incidence of hop nettlehead or cherry leaf roll virus. In collaboration with the N.A.A.S. some progress has been made towards devising a standardized technique for the efficient extraction of the above group of nematodes from various soil types.

Pollinating insects

Preliminary observations on the insects present on apple blossom in grass and cultivated orchards have shown that species of Diptera and Hymenoptera were most abundant in 1961.

Assessment of injury due to pests

Analysis of the effects of fruit tree red spider mite on growth, initiated by the Plant Physiology Section in 1960, has continued as a collaborative project. On potted plants of Brompton plum there was a marked reduction in root weight ; extension growth was also affected. No effect on growth of Crab C apple was detected but dry weights have yet to be obtained. An investigation of the possible effects of the chemical treatments used to keep the control plants free from mites is also in progress.

Nematode investigations

Collaborative work on the growth response of apple to *Pratylenchus penetrans* (Cobb) is continuing at Harrow, Ontario, Canada. Studies on the host-parasite relationship of this nematode under microbiologically sterile conditions are being extended to cherry.

By means of pot experiments it is hoped to estimate the relative effects, as components of the apple replant problem, of parasitism by *P. penetrans* and inhibition by unknown soil-borne factors arising from the previous growth of apples. Extension growth records have already shown that both components are depressive and can act separately or together.

In collaboration with the Pomology Section field trials have been established to evaluate the effect of soil fumigation before planting in relation to replant problems in apple and cherry.

PUBLICATIONS DURING THE YEAR

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D332 BRIGGS, J. B. (1961). **A comparison of pitfall trapping and soil sampling in assessing populations of two species of ground beetles (Col. : Carabidae).** *Rep. E. Malling Res. Sta. for 1960*, 108-12.

D333 DICKER, G. H. L., and MUIR, R. C. (1961). **Current research on the control of fruit pests.** *Advanc. Sci., Lond.*, **18**, 129-34.

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D336 PITCHER, R. S., and JHA, ASHARFI (1961). **On the distribution and infectivity with arabis mosaic virus of a dagger nematode.** *Plant Path.*, **10**, 67-71.

D337 (Q94) COLLYER, E., and KIRBY, A. H. M. (1959). **Contrasting influence of certain fungicides on orchard fauna in south-east England.** *Proc. IV int. Congr. Pl. Prot., Hamburg*, **1**, 949-51.

PLANT PROTECTIVE CHEMISTRY

Analytical methods

The methods developed for deposit and residue determinations for chlorinated hydrocarbon insecticides by microbioassay and by chemical analysis have been published (Q107-8).

Collaborative work with the Entomology and Plant Pathology Sections has called for the inclusion of methods for determining residues of lead, thiram, and dicloran (2,6-dichloro-4-nitroaniline), and the refinement of methods for sulphur and dinocap.

Use of insecticides on top fruit

Codling moth

In further collaborative work with the Entomology Section, attention was focused on the performances of lead arsenate, azinphos-methyl (*OO*-diethyl S-(4-oxo-1,2,3-benzotriazin-3-ylmethyl) phosphorodithioate), *O*-1-naphthyl *N*-methylcarbamate, and DDT, and chemical analyses were carried out to study the levels maintained by selected combinations of concentrations and timings. Persistence of deposits of *O*-1-naphthyl *N*-methylcarbamate from low-volume applications, with or without an adjuvant intended to increase persistence, has also been studied. Of four insecticides brought into these investigations for the first time, chemical determinations were made with respect to 1,1-dichloro-2,2-di-(4-chlorophenyl)ethane (DDD). In this year's trials, both lead and arsenic present in harvest residues from lead arsenate sprays have been determined, as the two elements may weather at somewhat different rates.

Determinations of lead and arsenic on fruit from a mature plantation sprayed at medium volume indicated a large difference in deposits at various heights in the trees, and further work on spraying efficiency is planned.

Fruit tree red spider mite

The trial begun at Writtle, Essex, in 1959 has been continued in collaboration with the Entomology Section. One half of the orchard continued to receive two applications of the sprays applied in previous years, but the treatments were again changed on the four plots in the other half. Chemical evidence confirming satisfactory initial deposits was obtained, but so far no evidence of failure to control the pest has emerged.

Information concerning the fate of deposits of phenkapton, 2,4,5,4′-tetrachlorodiphenyl sulphone, and 2,2,2-trichloro-1,1-bis-(4-chlorophenyl)ethanol in the above trial, and in other trials carried out at East Malling, has been published (p. 113).

Soil residues

Analyses of soil samples from an orchard from which plum trees had been grubbed, following annual applications to the trees from 1954 to 1959 inclusive of BHC at a rate of 0·31 lb per acre, showed that 0·24 lb per acre was still present in the top 12 in. of soil, a level regarded as too high for potatoes to be planted. Further analyses are planned after another year has elapsed.

Outside trials

In the course of trials by the N.A.A.S. in south-eastern England and at the Horticultural Experiment Station, Luddington, and by the N.I.A.E. in Somerset, deposits of DDT on buds, blossom-trusses and foliage were measured to establish the levels achieved and so facilitate the biological interpretation.

Use of insecticides on soft fruit

Strawberry seed beetle

The data obtained for deposits and residues of dieldrin and aldrin, both on fruit and in the soil, have been published (Q109).

Black currant gall mite

A paper on harvest residues of endrin on black currants has been accepted for publication. Observations made in several trials on phytotoxicity of fluoroacetamide to this crop are included in this Report (p. 107).

Bactericides

Work by the Plant Pathology Section has shown that control of bacterial canker in cherry can best be achieved by reducing the numbers of bacteria present on leaves in the autumn to as low a level as possible before leaf-fall. Bordeaux mixture, safened with a vegetable oil, has been found superior to colloidal copper oxychloride for this purpose, but remains an unpopular spray material. There is, therefore, a need for more convenient bactericides that will be safe and effective. Attempts were therefore made to devise a laboratory test that would provide adequate information about toxicity of various substances towards the causal organism, *Pseudomonas mors-prunorum*. Although the method will need refinement, information has been obtained that is concordant with field experience, and tests have been made with a number of commercial germicides, mainly surface-active compounds or sources of ' active ' chlorine.

A joint field trial with the Pathology Section suggested that nothing superior to Bordeaux mixture has yet been found.

Fungicides

Chemical control of powdery mildews

The new British preparation of dinocap (2,4-dinitro-6-(1-methylheptyl)phenyl crotonate, formerly referred to in these Reports as DNOPC) was found to be fully equal in the greenhouse test to the American product, both as the technical active ingredient formulated with Tween 80 and Triton X-100 and as the commercial wettable powder. A German product, based on dinoseb dimethylacrylate, although as safe as the dinocap preparations, was much inferior for apple mildew control. It was again confirmed that the crotonic ester of dinoseb is unsafe on apple ; the contrast in the effect on the phytotoxicity of dinoseb of esterification with dimethylacrylic acid instead of crotonic acid is most striking as well as surprising.

Results comparable to those for DNOP were obtained with thioquinox (quinoxalinyl-2,3-trithiocarbonate) and its 5-methyl homologue, but 3,5-di-*tert.*-butyl-4-nitrophenol was much less active and very phytotoxic under the conditions of the test. Two esters of dimethyldithiocarbamylcarbinol were tested ; both were safe, but the control of mildew by the acetate was much inferior to that given by the benzoate.

The excellent curative action of the cationic surfactant, didecyldimethylammonium bromide, was confirmed ; other cationics have been less effective.

The high degree of control given by the organophosphorus compound, W.P.155, both by preventive and curative action, was confirmed, but mildew was not prevented on young leaves when fully-expanded leaves on the same shoot were dipped in a suitable formulation 24 hours prior to inoculation.

Collaboration with the Fruit Nutrition Section was continued on the relation of magnesium status of apple rootstocks to susceptibility to mildew ; the results are presented on p. 91.

Attempts to use the settling-tower for evaluation of chemicals for control of strawberry mildew have so far failed as none of the susceptible varieties tested would ' take ' the disease sufficiently on the upper surface of leaves. A number of experiments were carried out in which inoculation was achieved by tapping the leaves of infected plants over the under surface of the test plants ; control in these tests was poor with lime-sulphur and with dinocap, but good with didecyldimethylammonium bromide. However, in a small-scale field trial on Cambridge Rearguard, lime-sulphur and dinocap proved effective and the cationic surfactant was a little inferior.

A small-scale trial was set up to evaluate a wettable powder based on 2,6-dichloro-4-nitroaniline, but the very low level of the disease made the trial unreliable. Chemical analyses of deposits on foliage and on fruits were made in both this and another trial involving the use of thiram and carried out by the Plant Pathology Section.

Field trials

Trials on apple rootstocks and dwarf pyramids have continued in collaboration with the Plant Pathology Section. The 1960 trials confirmed that DNOP gives as good control of powdery mildew as the crotonic ester, dinocap ; neither compound gave adequate control when applied as a concentrate.

Assistance has been given to the Pathology Section in calibrating the new spinning-disc spraying machine, obtained from the N.I.A.E., both as regards droplet size and distribution. Sulphur deposits from this machine on apple foliage have been measured chemically.

Deposits of captan on pear foliage and fruits were measured in a trial by the Plant Pathology Section in which a constant dose was applied in various volumes of spray.

Phytotoxicity

Exceptionally late frosts (27th and 28th May) had a severe effect upon the apple plots on the phytotoxicity trials plantation, P.12, and no results could be obtained in the trial begun to investigate the russeting of Cox's Orange Pippin by 2,2,2-trichloro-1,1-bis-(4-chlorophenyl)ethanol ('Kelthane'). The fungicide 'shock' trial was continued for a fourth year; no severe damage followed the pink-bud application of PMC.

The trial of dinitrophenols on pears was not continued as there was insufficient fruit-bud, but it is hoped to resume this trial in 1962.

Frost damage also interfered seriously with the trial of systemic insecticides on plums.

A further trial of copper compounds on cherry was made in September. There was no evidence from the 1960 trial that the amount of copper deposited or persisting for a fortnight differed with the amount of lime used, or with the order of mixing. In 1961, 4½ pints cotton-seed oil per 100 gal of 4 : 6 : 100 Bordeaux mixture prevented defoliation as effectively as 6 pints; 3 pints had been ineffective in 1960.

In the trial on gooseberry, comparing lime-sulphur and dinocap in a mildew-control schedule, the crop was again light on both varieties. However, while neither fungicide caused any reduction on Lancashire Lad, both reduced crop on Leveller, bushes sprayed with lime-sulphur bearing hardly any fruit. In this trial, in which the bushes are sprayed once pre-blossom and twice post-blossom, it appears that it is the second post-blossom (mid-May) application of fungicide which is responsible for crop loss on Leveller; this application was not made in the first year of this trial, 1958, when no losses occurred.

Both frost and bird damage interfered with the trial of high versus low volume lime-sulphur on black currant, but shoot-length was rather less where neat lime-sulphur was applied.

Publications during the year

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Q105 ———, and Bennett, Margery (1961). **Phytotoxicity of certain fungicides on Lane's Prince Albert apple.** *Rep. E. Malling Res. Sta. for 1960,* 113-15.

Q106 Tew, R. P., and Sillibourne, Joan M. (1961). **Harvest residues of malathion on soft fruits and apples.** *Rep. E. Malling Res. Sta. for 1960,* 116-19.

Q107 ———, and ——— (1961). **Pesticide residues on fruit. I. Microbioassay of pesticide residues using the vinegar fly, *Drosophila melanogaster*.** *J. Sci. Food and Agric.*, **12,** 618-23.

Q108 ———, and ——— (1961). **Pesticide residues on fruit. II. Determination of aldrin, dieldrin and endrin residues by the organic chlorine and phenyl azide methods and by microbioassay.** *J. Sci. Food and Agric.*, **12,** 623-8.

Q109 ———, and ——— (1961). **Pesticide residues on fruit. III. Aldrin and dieldrin residues on strawberries with some reference to insecticide persistence in the soil.** *J. Sci. Food and Agric.*, **12,** 628-34.

FRUIT STORAGE INVESTIGATIONS IN COLLABORATION WITH THE DITTON LABORATORY

Apple manurial trial

After the very wet summer, losses from gloeosporium rots in the Cox's Orange Pippin from this trial were high and the main examinations were made during January and early February. Samples stored at 37° F and 32° F showed once again the influence of grass swards in reducing wastage by gloeosporium and breakdown. The effects of other treatments on wastage by gloeosporium were not pronounced but as in previous years applied potash reduced losses due to breakdown at 32° F. Samples were also stored under controlled atmosphere conditions and in spite of difficulties in maintaining the desired 5% CO_2 and 3% O_2 for these small samples, some interesting indications were obtained on the incidence of core flush. This trouble was more prevalent in the apples from trees grown in swards, and in those with applied potash, and was less in those with applied nitrogen or applied phosphate.

Various chemical analyses and physiological measurements were made on this fruit at Ditton Laboratory. The respiration at picking time did not indicate any differences in maturity that could be associated with manurial treatment.

The Biochemistry Section with the Ditton Laboratory has further investigated the organic acids of the fruits from certain of the manurial treatments.

Survey of commercial fruit

For the seventh consecutive season fruit growers in various parts of the country supplied Cox's Orange Pippin apples from marked trees in their orchards. These apples were stored in air at 36° F until 18th January and in controlled atmosphere (5% CO_2 and 3% O_2) at 38-39° F until 28th February. The main sources of wastage were gloeosporium rots and, in the controlled atmosphere, core flush. The results were consistent with those of the previous years, showing relatively little effect of cultural treatments but marked effects of soil, age of trees, and location of orchard. Captan sprays again helped in reducing losses by gloeosporium. Losses from this cause, and from breakdown and bitter pit, were checked by controlled atmosphere storage but core flush was more prevalent. Losses from all these causes were heavier where the average size of fruit in the sample was large.

Twelve of the orchards with two of the labelled trees receiving less applied nitrogen than the other two were visited during July and leaf samples taken for analysis by the Fruit Nutrition Section.

A heavy crop was carried by the 3-year-old trees on M.IX propagated from selected Cox's Orange Pippin trees. The trees had been selected for the shape, colour, and skin finish of the apples or for their storage characteristics. One selection has produced a red sport. Wastage from gloeosporium rots was unusually high for such young trees and the strains showed no differences in susceptibility to this disease. Because of the rots, it was not possible to study the incidence of storage disorders.

Fruit development in Cox's Orange Pippin

Various techniques for determining cell volume and number in the cortex of apples have been compared. Research was resumed on the cell volumes in apples from trees receiving contrasting manurial treatments, and from trees that were very heavily thinned in mid-July, after the period of active cell division had ended.

PUBLICATION DURING THE YEAR

T74 DENNE, M. PATRICIA (1961). **Observations on cell size and number in relation to fruit size in apples.** *Rep. E. Malling Res. Sta. for 1960*, 120-2.

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Part III

RESEARCH REPORTS AND REVIEWS

GENERAL

AMOS MEMORIAL LECTURE*

THE LIMIT OF PLANT PRODUCTIVITY

By PROFESSOR G. E. BLACKMAN, M.A., F.R.S.

When Wat Tyler and his Kentish men marched on London, it is apparent from the query posed by John Ball that in the Garden of England, all men were not gentlemen. Since then, the winds of change have been blowing with increasing vigour and to me it is a comforting thought that despite the wide range of your individual scientific and horticultural interests, you will all bear with me with gentlemanly patience and forbearance. With the subject I have chosen, it is inevitable that I shall bore some of you some of the time. All that I can hope to do is not to bore all of you all the time, especially as I shall have to begin with an introductory statement which some will regard as obvious.

All terrestial higher plants are compounded of the carbon dioxide obtained from the air and the water and major and minor nutrients supplied by the soil, and the driving force required for the syntheses of the complex from the simple is the light energy absorbed by the leaves. As a broad generalization it can be stated that the mineral ash of herbaceous species ranges from 4 to 15% of the dry matter with an average of somewhat under 10%. The nitrogen level is much more dependent on the stage of development. It may be less than 1% or exceed 4 in the early vegetative phase of legumes or of other species receiving much nitrogen. Thus, since the total mineral content plus nitrogen is small and changes slowly with time, it follows that on a daily basis the increase in dry weight of an individual plant is largely a resultant of the net gain in carbon products. I emphasize net gain since the gain is the difference between the quantities of carbon dioxide assimilated by the leaves during the hours of daylight and the smaller fraction which is lost by the respiration of the roots and shoot during the night. It again follows that the amount by which any plant increases in weight per day is primarily dependent upon two parameters : first, the net photosynthetic efficiency per unit surface of leaf and secondly the degree of leafiness. In fact, by a little calculus it can be shown that the rate of dry matter production per day of a single plant—the relative growth rate (R.G.R.)—is the product of the net assimilation rate (N.A.R.) and the ratio of the total leaf surface to the total plant weight, which is termed the leaf area ratio (L.A.R.). In other words, any factor which brings about a change in the relative growth rate basically does so by altering the net assimilation rate, or the leaf area ratio, or both.

Now let us first look at some of the more important factors which are known to affect the rate at which plants gain weight in the vegetative phase. Take, for example, the response to a nitrogenous fertilizer. There is no doubt that the faster growth is primarily brought about by a higher leaf area ratio because the production of more and larger leaves is favoured, often at the expense of root growth. Unless there is an extreme deficiency, the net assimilation rate is unaffected by the level of nitrogen, but the apple appears to be an exception : it is seemingly more sensitive to nitrogen deficiency.

Coming next to phosphorus, the acceleration in growth of a deficient plant induced by an enhanced supply is usually related both to a higher net assimilation rate and a larger leaf area ratio but in this instance leaf and root production are in better balance. Turning to potassium there is a shift in the physiological emphasis : with an increasing deficiency the net assimilation rate is depressed first and then the leaf area ratio.

I wish I could extend these generalizations to the remaining elements which are essential in plant nutrition, but this cannot be done because not enough observations have been made. In my opinion this gap in our knowledge wants filling. Much good and careful research has gone into both the identification of the symptoms in different species, which are brought about by a lack of the individual elements, and the means for rectification. I am aware that for 1-year rooted shoots of M.VII rootstock,

* The Fourteenth Amos Memorial Lecture, delivered at East Malling Research Station on 16th November 1961.

compared with a lack of iron, the omission of magnesium from the culture solution causes a smaller depression in the net assimilation rate and a larger reduction in the leaf area ratio. What we know imperfectly for these and other trace elements is the level of deficiency that has to be attained before growth is arrested. Under some conditions it is debatable whether a level which can be detected visually does, in fact, slow down the rate of growth.

We are on surer ground for facts again when we come to the most important environmental factors —namely water, temperature and light. Under conditions of drought both the leaf area ratio and the net assimilation rate are decreased. Because seasonal changes in light and temperature are highly correlated, their inter-related effects on the rate of growth are complex and as a first approach I propose to consider the results of experiments where the light conditions have been altered, without appreciable changes in temperature.

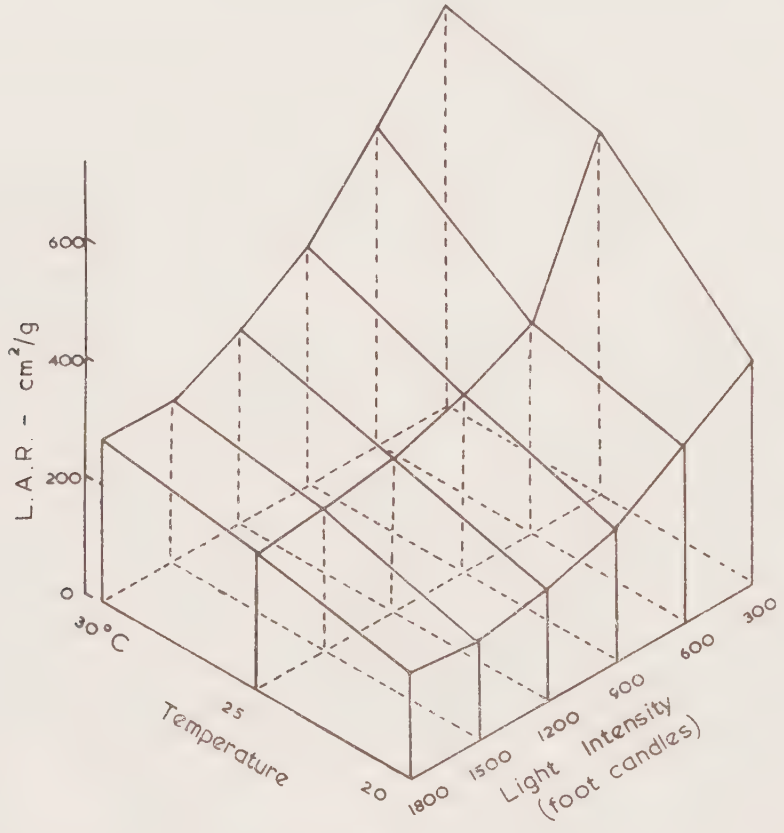

FIG. 1

The interacting effects of temperature and the intensity of continuous illumination on the leaf area ratio of *Salvinia natans*

It was in 1933 that I first became interested in the effects of a reduction of the light level on the growth of *widely spaced* plants and in the intervening period the reactions of some 22 species to shading under the conditions of the southern half of England have been recorded. For every species it has been demonstrated that as the light level is reduced from full daylight to a quarter daylight the net assimilation rate is depressed, but the leaf area ratio is increased—both in a curvilinear fashion. From what I have already said, it is apparent that this pull-devil pull-baker relationship determines the effect of shading on the product—the relative growth rate. If the reduction in the net assimilation rate is relatively greater than the proportionate increase in the leaf area ratio, then all degrees of shading will diminish the relative growth rate. If the reverse happens, then there will be a specific level of shading at which the relative growth rate is optimal. It is of considerable significance that for only one species, *Geum urbanum*, has it has been found that the relative growth rate is enhanced by a moderate level of shading. If the other plants can be regarded as representative of crops and species found in open habitats, then it must be concluded that, where the levels of nutrients, water, and temperature are

favourable, the ultimate growth rate is determined by the daily solar radiation received in a cool temperate climate such as ours. For warmer regions with higher levels of incoming radiation there is still a paucity of facts. At the Waite Institute in Australia, Black has shown that throughout the year, the amount of light energy received per day determines the rate at which plants of *Trifolium subterraneum* gain weight. On the other hand, there is evidence that in some regions receiving at midsummer very high levels of radiation, e.g. Israel, light can reach a supra-optimal level.

Turning to the influence of temperature, in two years, we measured over consecutive weeks from May until September the growth of batches of young sunflower plants. By appropriate statistical techniques it was possible to separate the effects of temperature from those of the light energy received per day. There was clear cut evidence that the leaf area ratio is positively dependent on temperature. When the experiment was repeated by Hodgson and Sampford* under the cooler conditions of the

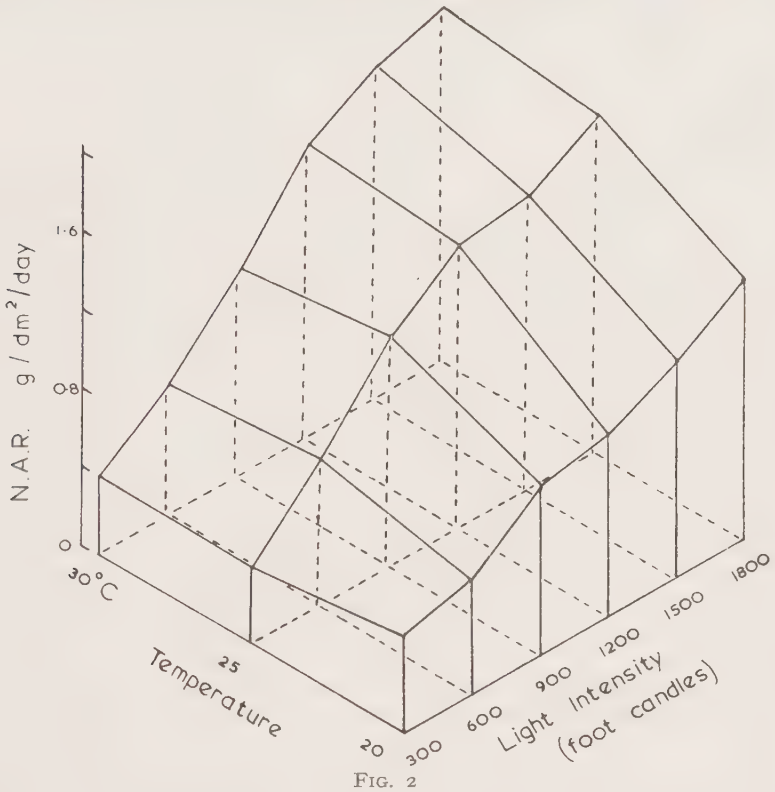

Fig. 2

The interacting effects of temperature and the intensity of continuous illumination on the net assimilation rate of *Salvinia natans*

Scottish Horticultural Research Institute, it was found that there was no effect of temperature on the ratio. On the other hand, for the bean (*Vicia faba*) and duckweed (*Lemna minor*) the ratio increased with rising temperature. Using chambers where the conditions of light and temperature can be controlled, the positive and negative dependences of the ratio on temperature and light have been confirmed at Oxford for radish and the aquatic tropical fern, *Salvinia natans*. Fig. 1 shows that the interacting effects of light and temperature can be very considerable.

For the Scottish experiments the net assimilation rate of each plant was enhanced by an increase in temperature but not so at Oxford. In Australia the net assimilation rate of *T. subterraneum* was determined by the light factor since the positive effect of mean maximal temperature balanced the negative effect of mean minimum temperature. For *S. natans* it is again evident from Fig. 2 that the effects of light and temperature are markedly inter-dependent. These divergences demonstrate that there are undoubtedly complex interactions between tree responses of species and the ranges of light and temperature to which they are subjected.

Although in all these investigations light and temperature exercised somewhat different effects on either the net assimilation rate or the leaf area ratio, with one exception they demonstrate that the

* I am indebted to Dr. Hodgson and Dr. Sampford for allowing me to quote their as yet unpublished results.

relative growth rate is dependent on both the mean temperature and the solar radiation received per day. Those of you who are not expert in these fields and therefore, in the first instance, turn to text books, may be puzzled. In the chapters on photosynthesis, and indeed in some recent papers, there are tables or figures which seemingly demonstrate for isolated shoots or individual leaves that above a level of 2,000-3,000 foot candles there is no further rise in the rate of carbon dioxide fixation by a large number of species, including many crops. Elsewhere it will be pointed out that the maximum intensities in the open can reach intensities of 8,000-10,000 foot candles which are greatly in excess of the optimum for assimilation.

How can these facts be reconciled with the field experiments I have been describing? My first comment is that it is not always valid to extrapolate the results for isolated leaves or shoots to the behaviour of whole plants. My second is that there are many pit-falls in measuring at high light intensities the rate of photosynthesis in small chambers. There is a third and much more important consideration, namely that in most natural or man-made communities the individual plants do not grow in isolation but are relatively crowded together and, except in the seedling stage, shade each other. As a result, the degree of mutual shading will affect the light intensity at which photosynthesis is optimal.

This important interaction was brought out by the investigations of Müller in Denmark who measured, under field conditions, the rate of photosynthesis of a barley crop at different stages of development. For young plants when there was little mutual shading the assimilation rate reached a maximum value at about 3,000 foot candles. But later, when the total leaf surface had doubled, the rate was still rising at intensities in excess of 5,000 foot candles. Put in another way, the effective utilization of high light intensities on sunny days becomes greater as the total leaf surface increases.

This type of inter-relationship also holds for individual plants or trees where the leaves shade each other. For example, Kramer and Clarke found that, whereas for single mature needles of *Pinus taeda* the maximal rate of photosynthesis was reached at 3,500 foot candles, for whole 2-year-old trees the photosynthetic rate was still rising at an intensity of 10,000 foot candles.

Watson and his co-workers at Rothamsted were amongst the first to emphasize the importance of the ratio of the total leaf surface to the ground surface—the leaf area index—in determining the rate of dry matter production and they followed the change in the index from emergence to harvest for a range of arable crops. Clearly, in the early vegetative phase when there is much bare ground, the incoming radiation which is not intercepted is 'wasted'. As the canopy closes the percentage of light which reaches the soil surface falls progressively and for individual crops there must be a value for the index which allows of the maximum utilization of the solar radiation in assimilation. It also follows that the longer the index is maintained at, but does not exceed, the optimal value, the greater will be the total accumulation of dry matter. As would be expected, the Rothamsted investigators showed that the span of a full and green canopy varied between crops, being shortest for spring barley and longest for sugar-beet.

On the basis of these considerations, it can further be concluded that the rate at which dry matter production is produced per unit of ground is dependent on two components : the leaf area index and the mean net assimilation rate. As the leaf area index rises, so more of the light is intercepted, but at the same time the mean net assimilation rate is diminishing because, due to greater mutual shading, the average amount of light received per leaf is falling. In other words, the highest rate of dry matter production will be achieved when the *product* of the leaf area index and the net assimilation rate is greatest.

As a next step in the analysis, I propose to discuss briefly the limits of light interception within a plant population. First, it is obvious that the fall in the light intensity from the top to the bottom of the plant is clearly dependent on the stage of development, the density of the individual plants, and the habit of growth. At Oxford some years ago we measured, over the growing season, the degree of shading at ground level for four densities (11, 25, 39 and 55 plants/m^2) of *Vicia faba*. From Fig. 3 it is evident that in mid May 96% of the light reached the bottom of the plants at the lowest density, but only 57% at the highest density. By mid June, when the plants were in full flower the corresponding figures were 31 and 3% and at the beginning of August, when most of the leaves had been shed, there was little difference between the lowest and highest densities. It is of interest to note that in mid June at the highest density the interception of light was equal to that of a mature beech wood.

So far, the maximal interception has been observed in pastures. For example, Black in Australia found that in dense stands of *Trifolium subterraneum*, interception was complete before ground level was reached. Moreover, the depth to which light penetrated was dependent on the variety. In one experiment for the last sampling occasion it can be concluded that the light intensity was negligible at a height of ca. 2 cm in one variety and 15 cm in another. From these studies of the light gradient it is apparent that where the gradient is steep the intensity will ultimately fall below the compensation

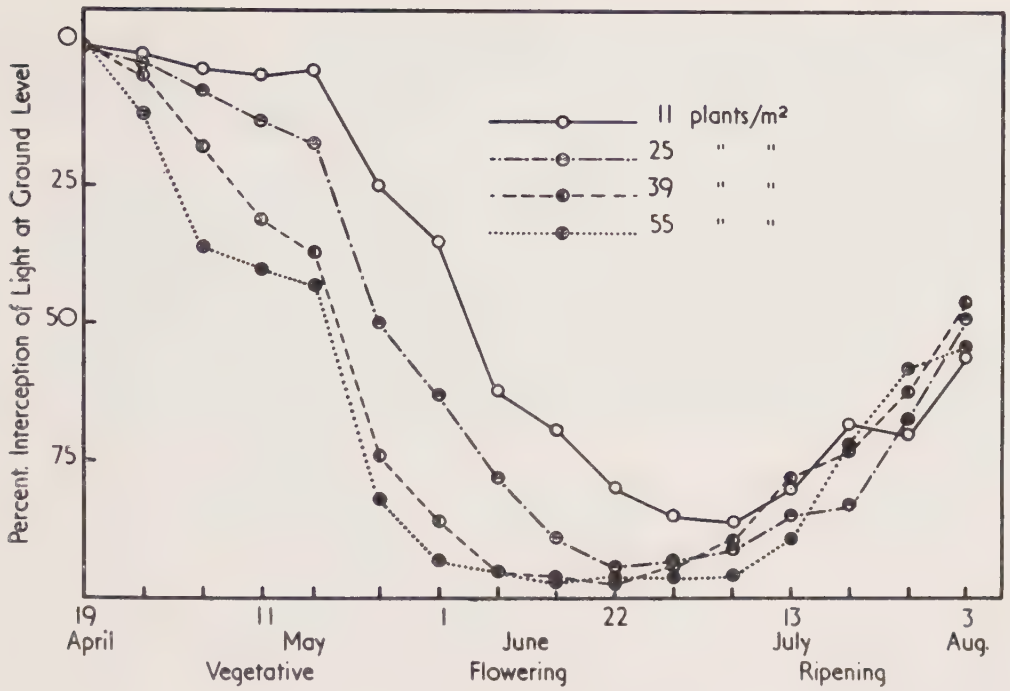

FIG. 3

The effects of stage of development and the density of populations of *Vicia faba* on the percentage of incoming radiation which reaches ground level

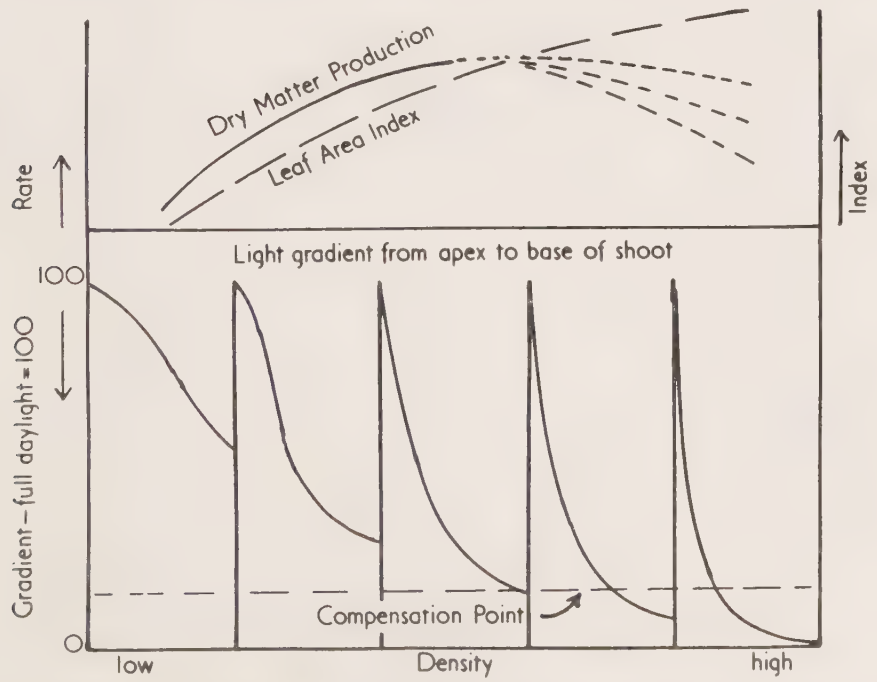

FIG. 4

Schematic diagram showing (*a*) the inter-relationships between density, leaf area index and the rate of dry matter production per unit area and (*b*) the change with density in form of the light gradient from the apex to the base of the stem

point, i.e. the level when over 24 hours photosynthesis just balances respiration in the individual leaves. Thus any leaves which *persist* at intensities below this point will be ' physiologically parasitic '.

In an attempt to clarify the complex inter-relationships between the rate of dry matter production, plant density, the leaf area index and the light gradient, I have drawn up a scheme which is shown in Fig. 4. In passing I would however emphasize that I do not claim that it is entirely original since a similar approach has been adopted by Donald and others.

For simplicity I have considered an annual plant with leaves uniformly distributed up a single stem sown at a varying density and looked at when it is growing actively in the vegetative phase. As the density is increased, the leaf area index will rise and the light gradient from the top to the bottom of the shoot will steepen. At low densities, the light interception will be far from complete and the rate of dry matter production per unit area will likewise be low. At very high densities, the light gradient will be so steep that the light received by the bottom leaves will be below the compensation point. There will be an intermediate density where the lowest leaves will be just above the compensation point, and under these conditions the leaf area index will be ' optimal ' and the rate of dry matter production maximal. The change in the rate of dry matter production at supra-optimal levels of the index will be dependent on the competitive ability of the lowest leaves to withdraw substrates from the remainder of the plant.

Schemata, like puddings, require proof and I now propose to produce supporting evidence which I hope you will find palatable. To do this I must refer to recent investigations which Dr. Brittain and others have carried out at Oxford. Since the data have not been fully worked out, the results given in Figs. 5 and 6 are only given in a generalized diagrammatic form.

In the individual experiments, each species was planted at a wide range of densities in boxes and on a number of occasions replicated samples were withdrawn and measurements made of the root, shoot and leaf weights of the individual plants, along with the leaf area. From the data of successive sampling occasions it was possible to calculate for each density the relative growth rate, the leaf area ratio and the net assimilation rate of the individual plants, together with the rate of dry matter production per unit area and the leaf area index.

The trends for an experiment with radish are given in Fig. 5. Taking first the data for the indivi-

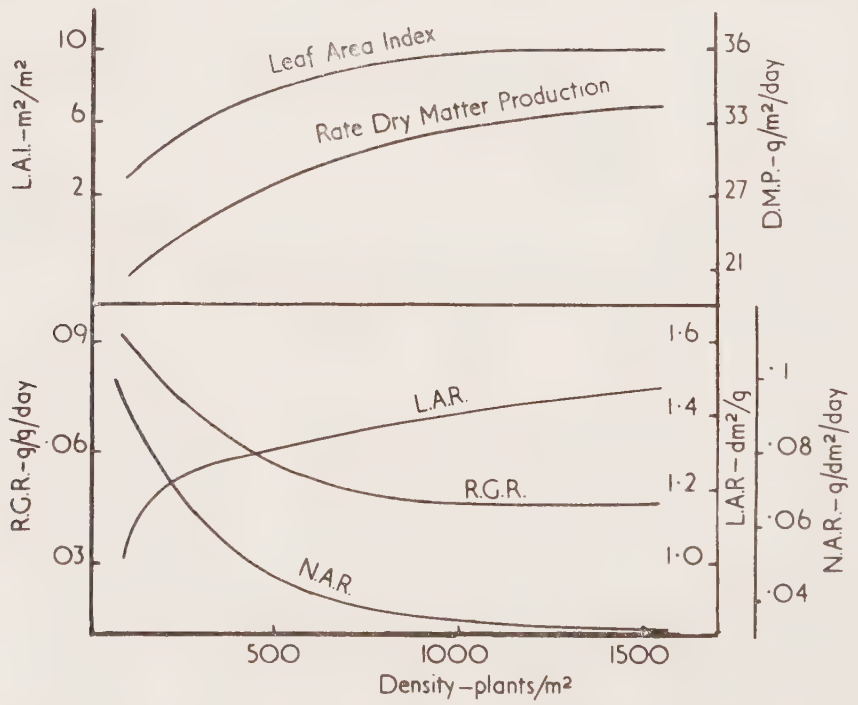

Fig. 5

The effects of varying the density of radish (*Raphanus sativus*) on (*a*) the rate of dry matter production and the leaf area index of the whole population and (*b*) the net assimilation rate, leaf area ratio and relative growth rate of individual plants

dual plants, the relative growth rate and the net assimilation rate decrease with increasing density. On the other hand, the leaf area ratio goes up ; this is not surprising when it is recalled that shading increases the ratio. Turning to the rate of dry matter production, it is to be noted that the rate and the leaf area index continue to rise up to the highest density. In other words, a compensatory level has not yet been reached where the rise in the leaf area index is offset by a corresponding fall in the net assimilation rate.

In the second experiment conducted with *Scilla hispanicus* the results are very different (see Fig. 6). With increasing density there comes a point where both the relative growth rate and net assimilation rate change from positive to negative values. As a consequence the rate of dry matter production is highest at the lowest density and is reduced to zero before the highest density is reached. The question which immediately arises is what determined the disparate reactions of the two species. The first point to be noted is the major difference in the magnitude of the leaf area indices. For radish, between the lowest and highest densities the range of the index was from less than 3 to about 10. In contrast, for *S. hispanicus* the index is already above 4 at the lowest density and reaches a value of no less than about 36 at the highest. It is therefore reasonable to conclude that for *S. hispanicus* at the highest density, the degree of mutual shading was far more intense and that much of the leaf surface was exposed to a light intensity below the compensation point.

Another factor which must be taken into account is the habit of growth. Radish has a more or less rosette like habit while for *S. hispanicus* the dispositions of the strap-shaped leaves resembles an inverted cone. For *S. hispanicus* it was also observed that at the highest density the leaves were noticeably longer and that they were the first to be beaten down by rain. It is, therefore, highly probable that this lodging of the leaves was a contributory factor in accentuating the steepness of the light gradient and thereby depressing further the mean assimilation rate.

The part played by leaf shape and arrangement in determining the potential productivity has in recent years excited the interest of investigators in the U.S.S.R., Japan, Australia and this country, but so far the consideration has been largely on a theoretical basis and I now propose to join in with some further theory. For simplicity I will start with leaf arrangement and in the schema set out in Fig. 7. I have selected four types A to D where the leaf area ratio is identical but the disposition of the leaves on the stem is different. Alongside are plotted the likely light gradients from the top to

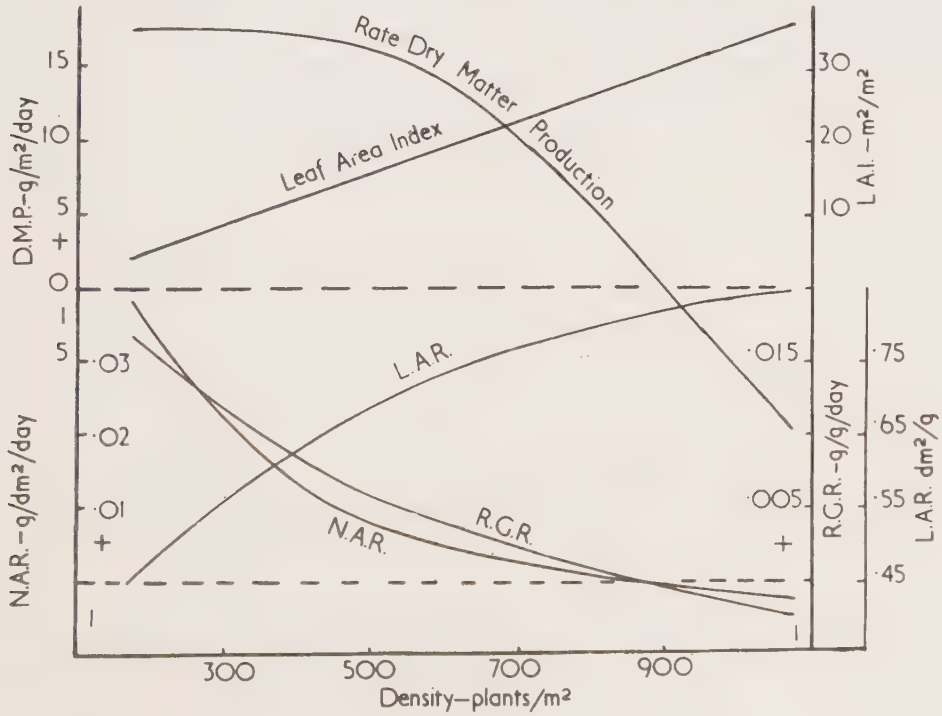

FIG. 6

The effects of varying the density of *Scilla hispanicus* on (*a*) the rate of dry matter production and the leaf area index of the whole population and (*b*) the net assimilation rate, leaf area ratio and relative growth rate of individual plants

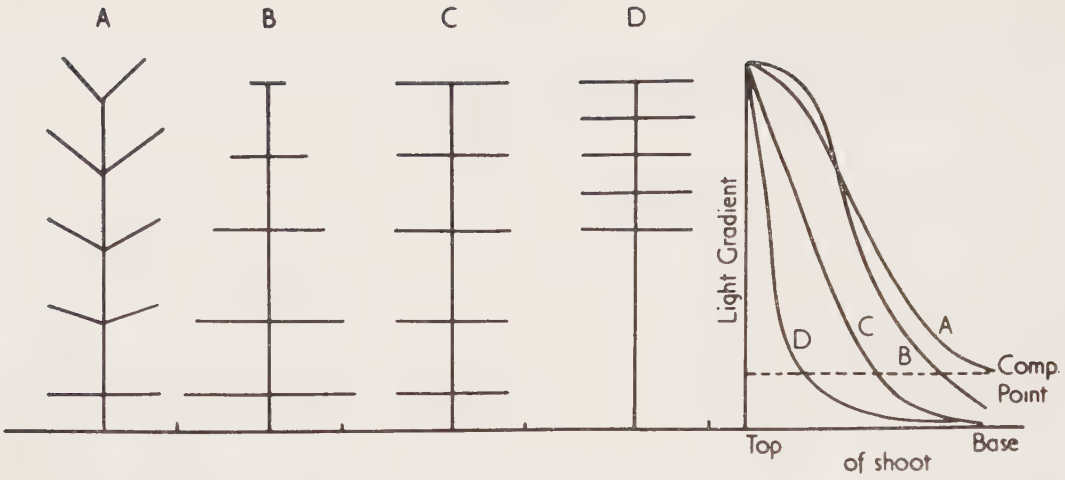

FIG. 7

Schematic diagram showing the influence of leaf pattern and arrangement on the form of the light gradient from the apex to the base of the stem, under conditions where the leaf area index is the same for each type and is such that for type A the bottom leaves are just above the compensation point

the bottom of the shoot, presupposing a common density for each type. On this basis, bearing in mind Fig. 3, it is seen that for the same leaf area index the order of the potential productivity is A>B>C>D.

You may have noted that whereas in types B-D all the leaves are shown in a horizontal plane, for A the angle of inclination becomes progressively greater from the bottom to the top leaves. The reasons for this choice are brought out in the next schema (Fig. 8) where the likely values for the net assimilation rates of the individual pairs of leaves are indicated by arrows for plants (A and E) with two contrasting types of leaf arrangement. Again, for simplicity it has been assumed that for all leaves there is the same curvilinear relationship between the net assimilation rate and the light level. Where the leaves are horizontal and a high proportion are bunched at the top of the stem as in E, there will be a much sharper fall in the light gradient down the stem compared with a well spaced arrangement of inclined leaves, i.e. A. Then again, save for the early morning and evening, the topmost horizontal leaves will intercept more light than the corresponding inclined leaves, but the effective utilization of the extra light absorbed by the horizontal leaves will be minimal, since the higher the intensity the

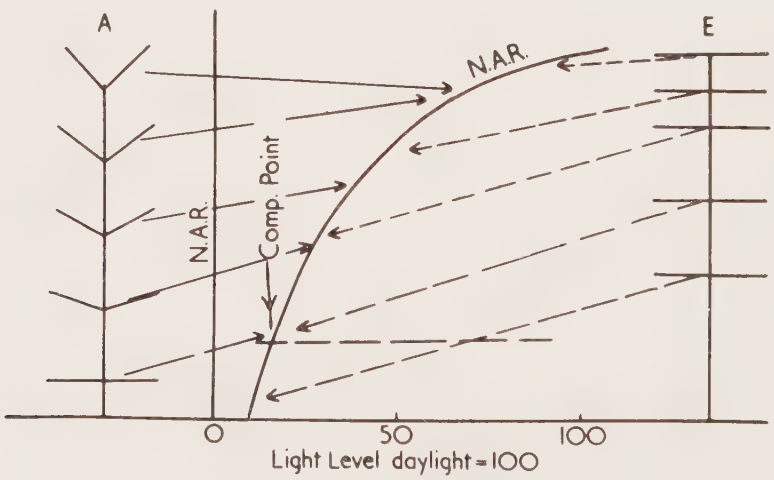

FIG. 8

Schematic diagram showing the net assimilation rates of the individual pairs of leaves down the stem for plants with contrasting patterns of leaf arrangement, under conditions where the leaf area index is the same for each type and is such that for type A the bottom pair of leaves is just above the compensation point

smaller will be the yield of photosynthetic products for a given amount of energy retained within the leaf.

Turning to the leaves at the bottom of the stem where the light intensity is low, the disposition of the leaves in a horizontal, as against an inclined, plane will be advantageous in intercepting the maximal amount.

So far, I have not mentioned leaf shape and here, applying the same arguments of the form of the light gradient, I would speculate that for open habitats narrow or finely divided leaves will be superior to round or cordate leaves. Similarly it can be advanced, more particularly for round leaves, that a spiral arrangement will be more efficient than a disposition in whorls.

Theories, if they are to stand up to criticism, must be supported by facts and in support I return to Dr. Brittain's researches at Oxford. In addition to radish and *S. hispanicus*, we selected a number of other species with divergent habits of growth with a view to determining what are the maximal rates of dry matter production which can be attained over relatively short periods when the leaf area index is optimal. The highest rate of dry matter production recorded was by that now rare British weed the corncockle (*Agrostemma githago*). This is to me a gratifying result since, of all the species tested, the corncockle fits best with theory. It has narrow leaves well distributed down the stem and the angles of the leaves conform to those of type A in Fig. 7.

So far I have been discussing the ways in which the leaf area index, net assimilation rate and leaf arrangement determine the productivity of the whole plant and not of its parts. Here it is clear that in some crop plants the optimal density for the part of economic importance may be different. For example, from Fig. 9 it is apparent that in the radish the optimal density for the production of the edible hypocotyl and root is much lower than that for the total weight of the plant.

Similarly it is known for maize (*Zea mays*) that in relation to total shoot weight, the optimal density for grain production is less : as an example I have given in Fig. 10 the results of one of Dr. Bunting's trials at Oxford. In America and in our investigations it has been established that the effect of high densities in suppressing the yield of grain varies between hybrids. Stinson and Moss in the United States have produced good evidence that this difference between hybrids is dependent upon their ability to withstand a high degree of mutual shading. When a range of hybrids were artificially shaded (0·66 daylight) the mean reduction in grain yield of those known to be tolerant of close planting was 20%, while for intolerant hybrids the reduction was 42%.

Now I would like to return to the corncockle for to the best of my belief it has so far achieved the world's record in the rate of dry matter production. The maximal rate was equivalent to the production of one ton of dry matter per acre every four days. Lest you should think that this a freak

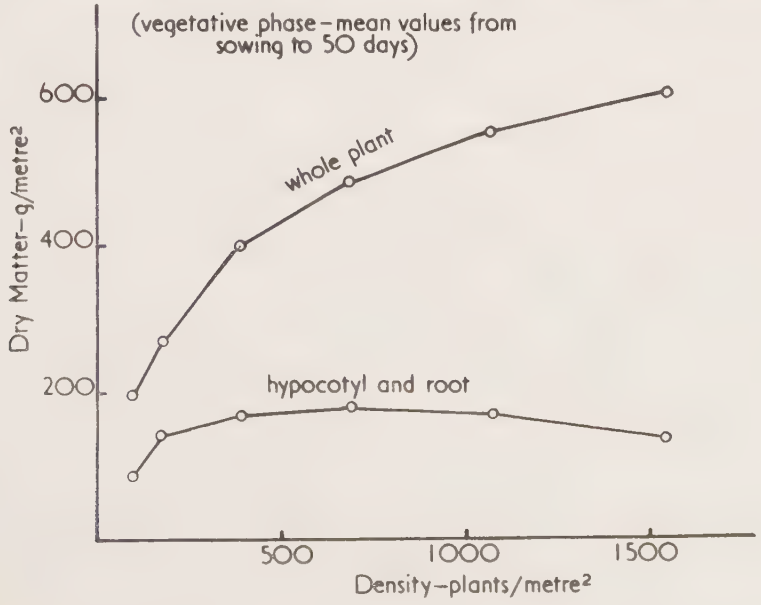

FIG. 9

The effects of varying density on (*a*) the dry matter production of the whole plant and (*b*) the hypocotyl and root of radish (*Raphanus sativus*)

result I would point out that for seven other species the equivalent time taken ranged from about 5 to 8 days. I would also stress that this rate is only achieved for a relatively short period when the leaf area index is optimal : after that there may be too many leaves.

This aspect is well illustrated by Donald's investigations with swards of *T. subterraneum*. He found that with time, the rate of dry matter production ultimately became negligible because of the very high leaf area index and the consequent intense self shading. On these premises it can be advanced that the best grazing management would be to arrange the stocking so that the index is maintained about a maximum value.

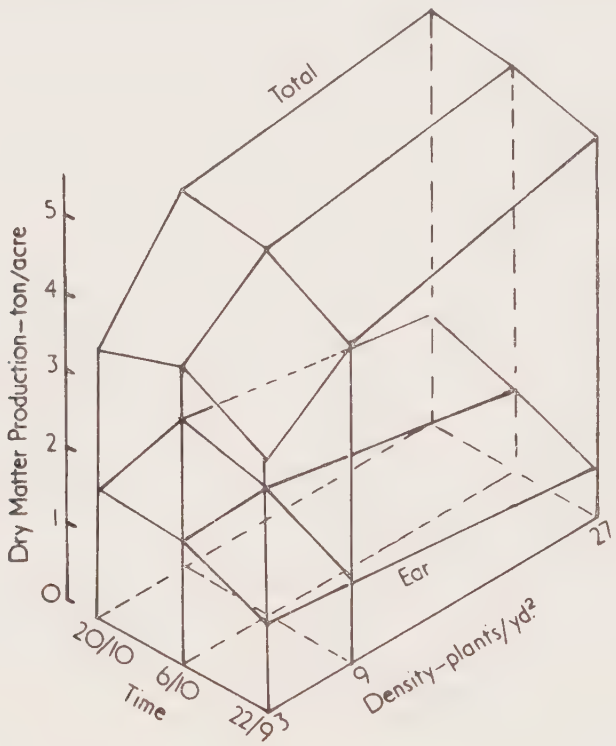

FIG. 10

The effects of varying density on the dry matter production of (*a*) the whole shoot and (*b*) the ear of maize (*Zea mays*)

For plants which are not normally defoliated I have already indicated that the highest productivity will be achieved when the leaf area index remains approximately optimal for a long time. In this connexion it is of some significance that at Oxford the two species which have given the highest yields of dry matter for the growing season—namely 6-7 tons per acre—are the artichoke (*Helianthus tuberosus*) and maize. Not only do these two species maintain a closed green canopy from June to October but the spatial arrangement of the successionally produced leaves is such that the bottom leaves are not heavily shaded at the optimal densities. In parenthesis, I might add that if a dwarfing gene is introduced into a maize hybrid there is usually a loss of productivity. It can be postulated that this loss, at least in part, is due to a greater mutual shading of the leaves, consequent upon a shortening of the internodes.

By this time, some of you who are more interested in the practices of fruit growing may be feeling like the Pigeon when she found Alice with her head in the sky above the trees. The Pigeon clearly regarded Alice as a suspicious character in her wrong station, and was well pleased when Alice started to get her head down to earth again. You will recall that Alice experienced considerable difficulty because her neck kept on getting tangled up in the branches and I have an equal reluctance to descend from theory to practice because my direct knowledge of fruit trees, bush fruits or strawberries is no more than meagre.

Perhaps with diffidence I may suggest that the concepts I have been expounding are basically applicable to perennials whether they be trees, bushes or herbs. I realize that there is the added complication that in any one growing season the influence of environmental factors will in part be

dependent on the extent and utilization of the reserves carried over from the previous years. Nevertheless, it can be concluded that cultural practices and season will exert a similar pattern of reactions for annual and perennial species. Balanced additions of nitrogen, phosphorus and potassium, jointly or severally, will ensure firstly that there is a rapid expansion of leaf surface at the beginning of the season, secondly that there is no premature leaf fall, and thirdly that the photosynthetic efficiency is maintained at a high level. The rapidity with which an effective leaf cover will be attained will likewise be dependent on the closeness of planting and the size of the individual. Seasonal variations in temperature and rainfall will also play their parts in determining leaf size, the rate of leaf production and their assimilatory effectiveness.

Coming lastly to the light factor, Mr. Maggs at this Station has shown that the growth of one-year-old apple trees is retarded by even slight shading and this being so, I am set wondering whether, in apple orchards, the interception of light by the leaf canopy is too low for optimal dry matter production. I appreciate that there is a need for frequent spraying and that an open frame-work has several advantages. But do less drastic systems of pruning or close planting inevitably lead to a loss of crop? If they do, is there a critical level of mutual shading below which there are no apples? As a corollary it would be of further interest to ascertain to what extent the carbon substrates for the individual apples are derived from the adjacent leaves or distant parts? I am minded to ask this last question because in sorghum it has been found by Li and Liu that from the dough stage onwards only the top three leaves contribute to grain production. Lastly, by analogy with maize, are there varieties which are more shade tolerant than others or in the long term could they be selected?

Similar queries can be posed about bush fruit but here I suspect that for old and large bushes the leaf area index may approach supra-optimal values. For strawberries it is more than a suspicion. Went observed that the compensation point for whole plants rose progressively with age and it can therefore be advanced that even though mature leaves may produce inhibitors of flowering, the loss of productivity in old strawberry beds is associated with too large a leaf surface. Thus the beneficial results of burning the straw may in part be a consequence of reducing the total leaf area.

Finally, while I have urged the importance of looking at cultural practices or the performance of varieties in terms of leaf area index, leaf pattern and leaf shape, there are further possibilities in the future of ordering these changes. We know how to remove leaves and we are beginning to learn how to keep them on, or to alter their shape. In some species we can make dwarf varieties tall with the gibberellins, and tall plants into dwarf plants with the new dwarfing compounds. It is also possible, under limited circumstances, to inhibit or promote flowering. At this point in the recitation of possible chemical wonders to come, those of you who are already much exercised about the complexities of the present day spraying programme may be hoping that I am back, and will stay, in Wonderland along with the two pieces of mushroom, the glass bottle and the gravel which turned into little cakes. To allay anxieties I hasten to add that such compounds may well not reach the reality of practice for decades. In the meantime, I am sure that Amos, in whose memory this lecture is given, as a man of observation and vision would agree with me that one must be allowed to dream because the advance of science is compounded of fact and fancy.

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POMOLOGY

DELAYED GROWTH OF APPLE SCIONS IN RELATION TO EARLY BUDDING, BUD CONSTRICTION AND SOME OTHER FACTORS

By N. G. SMITH, R. J. GARNER and W. S. ROGERS

When raffia was the usual tying material for budding, release or re-tying to avoid constriction of the budded rootstock resulting from growth during the remainder of the season was recognized good nursery practice. With the advent of plastic ties this requirement has received less attention. Observations at East Malling have shown that unintentional constriction can have effects on the growth of the maiden scion in the following year far more important and extensive than is commonly realized. The constrictive effect of a tie relates not only to its elasticity or otherwise, but also to the amount of growth made in the same season by the rootstock after budding ; that is, early or late budding can influence the amount of constriction.

Three experiments carried out at East Malling have thrown additional light on these questions : these investigations followed the observation that scion growth of Lord Lambourne and Fortune, budded on M.26 early in the season (30th July 1957) was unusually delayed.

Experiment 1, 1958-59

In this experiment five factors were considered :

(*a*) Two scion varieties, Lord Lambourne and Cox's Orange Pippin, on the rootstock M.26,
(*b*) early (29th July) and late (26th August) budding,
(*c*) any growth effects due to petroleum jelly smeared over the bud-shield (a normal measure to prevent egg-laying by the red bud borer fly (*Thomasiniana oculiperda*, Rübs.)),
(*d*) the effect of removing the wood from behind the bud-shield. It was thought desirable to check this point with M.26, though it was known that for other apple rootstocks this treatment of the bud-shield did not influence growth (Garner 1935),
(*e*) the position of the bud on the bud-stick.

The sixteen treatments, comprising two varieties, two times of budding, presence or absence of wood and of petroleum jelly were applied to 256 M.26 rootstocks in a factorial design, with confounding of the four-factor interaction. Thus 64 trees of each variety were budded early, and 64 late. There were 32 plots, each containing 8 trees.

Shoots for use as ' bud-sticks ' were cut from healthy young trees at one inch from the base of the current season's growth, and the lowest eight buds were used for each plot. The order of insertion of buds was recorded for each plot.

The bud-ties were ribbed polyvinyl chloride (P.V.C.) strips, which were removed after eight weeks.

Stem diameters of the rootstocks were measured at the time of budding and in the subsequent dormant season.

In the following growing season records were made each week to determine the time of bud-swelling and subsequently frequent measurements were made of extension growth.

Results

Of the factors under test, only time of budding affected the onset of growth of the scion bud. It can be seen in Table I that the majority of scions in late-budded plants began growth earlier than those budded in July. About 10% of the most precocious of the early-budded plants equalled the late-budded trees in size by the end of the season. A study of the individual growth rates of ' late starting ' plants in this experiment and in the following one reveals that, after shoot-extension began, the growth rate was in nearly every case similar to that for the ' early starting ' trees. Thus delayed growth of the scion buds resulted in smaller maiden trees.

Records of extension growth on some plots were complicated by differences in growth occurring in

TABLE I

ONSET OF SCION GROWTH IN THE MAIDEN YEAR (EXPERIMENT 1)

Percentages of scions making growth on the given dates

Observation dates	Dates of budding 1958			
	Lambourne/M.26		Cox/M.26	
	July 29th	August 26th	July 29th	August 26th
April 4 1959 ..	0	0	0	9·4
,, 9	0	0	0	20·3
,, 16	0	12·5	1·5	64·1
,, 23	20·3	53·1	28·1	85·9
,, 30	60·9	85·9	57·8	90·6
May 7	76·6	92·2	71·9	90·6
,, 21	93·8	95·3	81·2	92·2

strips and attributed to variations in soil fertility. As far as ultimate growth in the first year is concerned it is clear that early budding produced smaller trees, especially on land in poor condition (Table II). The average height of the maiden Cox on the less fertile land was 92 cm and 96 cm for the early and late-budded plants respectively ; the corresponding figures for Lord Lambourne were 84 cm and 94 cm.

TABLE II

EFFECT OF TIME OF BUDDING ON THE HEIGHT OF MAIDEN TREES (EXPERIMENT 1)

Variety and soil condition	Budded early —July 29th 1958		Budded late —August 26th 1958	
	Number budded	% which reached 3½ ft	Number budded	% which reached 3½ ft
Cox O.P. on ' poor ' soil*	39	56	56	64
Cox O.P. on ' good ' soil*	25	84	8	100
Lord Lambourne on 'poor' soil	48	12	41	46
Lord Lambourne on 'good' soil	16	87	23	96

* i.e. areas of poor and good growth respectively, see text.

The figures shown in Table III confirm previous findings that the position which a bud occupies on the bud-stick will have no influence on the growth it will make after budding, provided the bud is plump and is not removed from the softer terminal part of the shoot (cf. Cannon 1954). The two budding techniques investigated were the effect of petroleum jelly smears and of the removal of the wood from the bud-shield. From the following growth-means of maiden-stems* for the variety Cox, it is clear that neither of these treatments has a detrimental effect : petroleum jelly applied 93·4 cm ; petroleum jelly omitted 91·7 cm ; ' wood ' included 92·0 cm ; ' wood ' removed 93·0 cm. The averages quoted here and in Table III are computed from records of growth up to 13th August.

Experiment 2, 1959-60

In Experiment 2 an early-leafing rootstock (M.VII) was included, as well as the relatively late-leafing M.26, to test whether the effects of early budding were associated with duration of dormancy. Malling VII is one of the earliest leafing rootstocks, and commonly comes into leaf two to three weeks earlier than M.26. Eighty plants of each rootstock were budded on 18th July and 80 more on 20th August. There were eight replicates, each of ten trees, of each stock for each date.

* The term ' maiden-stem ' is used here for the vertical stem that grows from a graft in the first season.

Table III

Growth of maiden-stems (1959) in relation to the position of the bud on the ' bud-stick ', and to time of budding (Experiment 1)

Bud position†	Av. from 8 bud-sticks per variety			
	Cox/M.26		Lord Lambourne/M.26	
	July budded cm	August budded cm	July budded cm	August budded cm
The lowest two buds	99·0*	89·7	89·7	97·3
Buds 4 and 5	92·0	97·0	85·1	91·2
Buds 7 and 8	95·7*	92·0	87·9	99·6

* During 1959 it was found that more of the July-budded than the August-budded trees occurred in an area of particularly good growth, and the fact that some July figures in Table III are greater than August ones is attributed to this soil difference.

† Buds on each shoot were numbered serially, No. 1 being the lowest bud.

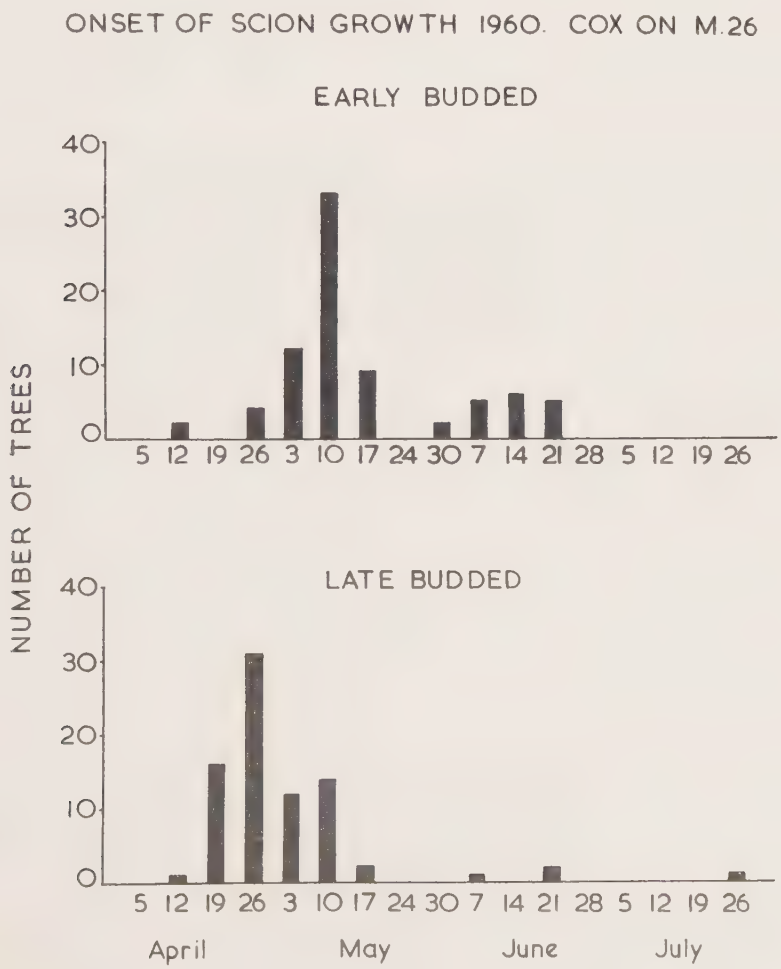

Fig 1

Onset of scion growth. Experiment 1

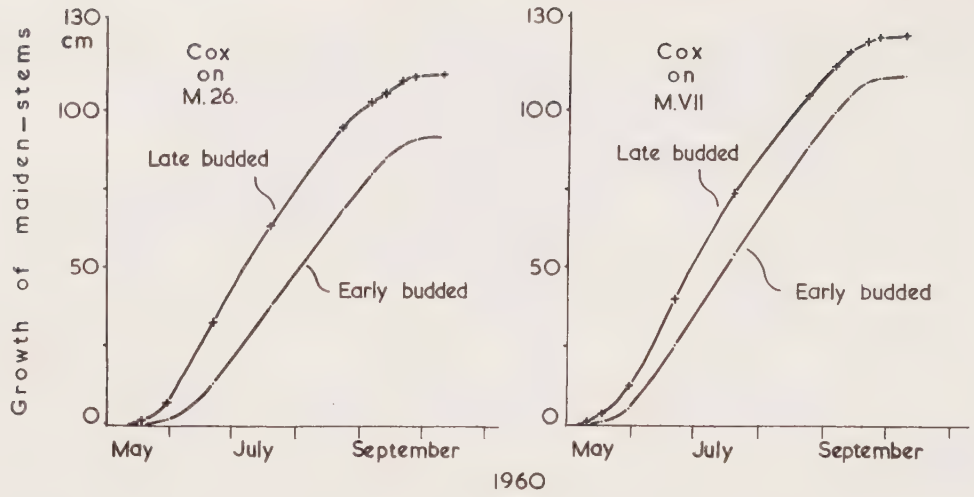

FIG. 2

Mean extension growth of main stems of early (18th July) and late (20th August) budded trees

One budder did the work and Cox buds from one tree were used. The ties, all P.V.C., were removed eight weeks after budding.

Results

The appearance of the areas adjoining the bud-shields, after the release of the ties, differed greatly. Around the bud-shields of plants budded early, the cortex had been raised by secondary tissue and a considerable proliferation of callus tissue had occurred at the cut edges. In about half these plants the callus completely covered that part of the bud-shield below the bud. However, with the late-budded rootstocks the callus along the T cut occurred only as a very thin fringe.

Fig. 1 shows the number of scion buds which had put forth leaves since the previous week. It is evident that in this trial also, most of the August-budded plants began growth a fortnight earlier than those budded in July.

Curves for the means of scion growth at various times in the first growing season are shown in Fig. 2. From these curves it can be seen that in both M.26 and M.VII early budding delayed growth in the following spring. Moreover, the curves show that once growth had begun, it proceeded at about the same rate with ' early ' as with ' late ' budded plants. Though about 10% of the early-budded trees of M.26 again produced excellent plants, the mean length of maiden stems was significantly less ($P<0{\cdot}01$) for the early- than for the late-budded trees, the differences being 20 cm on M.26 and 13 cm on M.VII (Fig. 2).

A good nursery tree should preferably be about 45 in. high, that is, it should have a scion length of 39 in. (99 cm) when budding has been done at 6 in. from the ground. The proportion of Cox/M.26 achieving this length by September 21st was 33·3% for the early-budded, and 78·5% for the late-budded. Similarly figures for Cox on M.VII were 73·1% for ' earlies ' and 93·2% for ' lates '.

Thus it is clear that budding in the second half of August rather than earlier gave a higher percentage of good saleable trees.

Experiment 3, 1960-61

The possibility that tie constriction following early budding delays bud development the following spring was examined in Experiment 3. One hundred buds each of Cox and Worcester were inserted in M.26 rootstocks. There were four treatments, randomized in five blocks of each variety, as follows :

(*a*) early budding, P.V.C. ties removed at 3 weeks,
(*b*) as (*a*) but ties removed at 8 weeks,
(*c*) early budding, polythene tape removed at 8 weeks,
(*d*) late budding, P.V.C. ties removed at 8 weeks.

The P.V.C. ties are orange coloured ribbed strips $\frac{3}{16}$ in. wide and 0·036 in. total thickness. The polythene tape is 1 in. wide and 0·0025 in. thick. Laboratory tests on the stretching characteristics

Fig. 3

Appearance of Cox buds in winter

A. Budded 21st July, P.V.C. tie removed after 3 weeks
B. The same but tie removed after 8 weeks
C. Budded 21st July, polythene tape removed after 8 weeks
D. Budded 29th August, P.V.C. tie removed after 8 weeks

of the two ties showed that their relations with load, time and temperature were complex. The stretching of the polythene, per unit width, varied from nearly four times that of the P.V.C. under some conditions to about the same as the P.V.C. under others. It seems likely that under the varying conditions of the field the constricting effect of the polythene tie, as the rootstock swelled, was about half that of the P.V.C.

'Early budding' was on 21st July and 'late' on 29th August. In treatment (*a*) the ties were removed on 11th August. By 15th August there was some slight opening of incisions in the rootstocks and the ties were replaced lightly and finally removed on 29th August. In the three other treatments ties were left intact for eight weeks. The diameter of every rootstock was measured on 18th July, at 3 in. above ground, before any budding began and again on 12th and 29th August and 15th and 23rd September. All rootstock shoots produced during the budding season were measured when dormant in the following winter, and the growth from the inserted buds was recorded in spring and summer 1961.

TABLE IV

EFFECT OF EARLY BUDDING AND BUD TIES ON GROWTH OF MAIDEN TREE (EXPERIMENT 3)

	Maiden height Worcester (cm)	Maiden height Cox (cm)	No. of laterals Cox	Mean length of laterals Cox (cm)
A. Budded 21st July, P.V.C. ties released after 3 weeks	88·4	108·2	14·0	20·5
B. Budded 21st July, P.V.C. ties released after 8 weeks	89·1	104·0	10·4	20·2
C. Budded 21st July, Polythene ties released after 8 weeks	91·6	110·4	11·7	20·5
D. Budded 29th August, P.V.C. ties released after 8 weeks	91·7	105·8	15·0	20·0
Significant diff. $P<0·05$	n/s	n/s	2·36	n/s

Results

In the year of budding the growth of the rootstocks, in diameter of stem and length of shoots, was unaffected by budding treatment. The appearance of the dormant buds and surrounding rootstock tissues varied according to treatment (Fig. 3). There was very little callus development following late budding (Treatment D), the rootstock stem remaining smooth, much as when first budded. There was much soft callusing at the cuts under polythene (Treatment C), probably due to moisture under the tie, but little sign of constriction. In Treatment B (budded early, tie released after 8 weeks) the bud was almost engulfed by rootstock development, and there had obviously been considerable constriction of the buds. In Treatment A (tie released early) the cuts were a little open at the vertical seams and somewhat raised, but there was no marked constriction.

The serial measurements of rootstock diameters showed that in July and August the rootstocks were thickening much faster than in September and October. In fact, in the 8 weeks following early budding, the increase in rootstock circumference 2 in. below the bud was 44%, while in the 8 weeks following late budding it was only 14% ; thus it is clear that the early-inserted buds suffered much greater constriction than the late-inserted ones, if the ties were not loosened.

In spring 1961 Cox began growth about $2\frac{1}{2}$ weeks before Worcester, but in both varieties the buds inserted last began growth first. There was little difference between the early-budded treatments, but buds of Treatment B (not released for 8 weeks) tended to be the last to start.

In this experiment, in contrast to Experiments 1 and 2, the maiden heights virtually evened up by late August and there were no significant differences in height, either of Cox or Worcester trees ; but in Cox, a variety given to the production of lateral shoots, there were significantly ($P<0·01$) more laterals under Treatments A and D than under Treatment B, with Treatment C tending to be intermediate (Table IV).

It is of interest to observe that the significant difference in vigour is due to an increase in number of laterals ; the mean length of laterals showed no significant difference between treatments.

Thus in Cox, early release of budding ties from rootstocks in rapid growth had mitigated the ill effect on growth previously associated with early budding. The tendency for the less restricting polythene to have a similar effect supports this conclusion.

Another feature, evident in the field and confirmed by a study of the figures, was that the trees of Treatment B (early-budded, late released) were more variable than the rest.

As trees of all treatments of the variety Worcester became virtually the same in size, by the end of the season after budding, it appears that not all varieties will show the same reaction to early budding and bud constriction ; but it is evident that the varieties Cox's Orange Pippin, Lord Lambourne and Fortune show a marked response to these factors. Within the limits of normal good nursery practice, these effects are not usually very large, but with certain varieties and in certain seasons they can be large enough to be of considerable importance, so they are certainly worth attention.

Discussion

The first experiment showed clearly that buds inserted in late July started growth later next spring than buds inserted in late August ; but position of the bud on the bud-stick, petroleum jelly smears and the removal of wood from the bud-shield had no effect on budbreak or growth.

In the second experiment rootstocks having widely different periods of leafing were used, budded early and late. Here again it was only time of budding which had effect ; the early-leafing rootstock M.VII did not hasten growth of the new scion compared with the late-leafing M.26.

The inverse relation between time of budding and onset of maiden growth was clear, but the underlying cause was not. An early start in spring had led to somewhat taller and sturdier maiden trees and the third experiment was designed to separate the factors of time of budding from constriction by the tie. Measurements of M.26 rootstocks in 1960 had revealed that within eight weeks of the time of budding the early-budded had added three times as much to their existing diameter as those late-budded and this rapid swelling could impose severe pressure on the newly inserted bud-shield and adjoining rootstock.

In the third experiment, growth following late budding was for all practical purposes equalled by that from early budding, provided the ties were released before severe constriction occurred. This finding is supported by the results from use of less constricting polythene, though this plastic has other features which require further study. It is hoped to test a wider range of tying materials in relation to time of budding and seasonal behaviour of rootstocks.

The more fundamental question of how early budding and constriction of the bud lead to delayed budbreak still requires elucidation. It may have some connexion with increased storage of growth inhibitors in the large amount of callus and parenchymatous tissue induced by early budding. Meanwhile, wherever early budding is done, it is clearly wise to avoid constriction, either by using readily stretched ties, or by early release of the ties.

Summary

Delayed growth of maiden apples can be caused by defects in nursery procedure. The major cause is traced to greatly increased constriction of buds by the tie, when budding is done early and followed by rapid growth of the rootstock. Care should be taken to release ties before they are too tight, or to use ties which are either very elastic or give way under strain.

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THREE TREE FORMS FOR PLUMS

By A. BERYL BEAKBANE and A. P. PRESTON

The effects of tree form on yield and other characters have been studied in apples (1,2,6) and in pears (5). Fewer pruning experiments comparing different tree forms appear to have been carried out with plums and none, as far as the writers are aware, have included an entirely unpruned tree or a summer-pruned pyramid. In the present trial these two forms were compared with half-standards in which the primary branches were treated with indolebutyric acid, to test its effect on branch angle, and with normal half-standards. The unpruned tree was expected to provide a large leaf- and fruit-bearing surface, with minimum labour requirements. The aim in forming the pyramid was to make a smaller tree with sturdy branches which would not be prone to break under the weight of crop. Although the trees are not yet in full bearing an interim report on yield, tree size, and branch breakage is given.

Lay-out and management

Maiden trees low-worked on the vigorous rootstock Brompton were planted during the winter of 1952-3 at 20 ft apart in a single row ; this arrangement was chosen to give full exposure to wind. The trial was designed with single-tree plots distributed within ten randomized blocks.

Unpruned

Apart from the removal of broken branches, and of suckers from the rootstock, the unpruned trees received no pruning at all ; they were not headed back at planting and no laterals were removed from the scion trunk.

Pyramid, pruned in summer

In April, following planting, the trees were headed back to between 5 ft and 5 ft 6 in., feathers being shortened to half their length. About the third week of July in the same year, branch leaders were shortened to about half their length to a downward bud except towards the base of the tree where they were pruned to a sideways- or upward-pointing bud. Shoots within 9 in. of the ground were removed. Laterals were pruned to between 6 and 8 in.

Routine pruning in subsequent years consisted of cutting back the central leader to half its length, branch leaders to 10 in., and laterals to 8 in. The central leader was pruned in early April, and the branch leaders and laterals in late July—usually about the third week. The branch leader and lateral pruning treatment remained the same throughout, but the central leader was dehorned in the fifth year to a lateral shoot arising on two-year-old wood. Thereafter the central leader was pruned to within 1 in. of its base in summer.

Half-standard treated with IBA

Half-standard trees were headed back to 4 ft 6 in. in the April following planting and the cut end of each tree smeared with a paste of IBA at 90 p.p.m. in lanolin. This treatment was included to test its effect on primary branch angle.

Lateral shoots arising on the trunk (feathers) were shortened to within 2 to 3 in. of their base at the same time. Primary branches were selected and pruned the following year to provide more leaders. For two more years laterals arising along the trunk were shortened to 2 to 3 in., then all growths on the trunk were removed completely. After the first three seasons, pruning consisted of the thinning out of crowded laterals, and the removal of broken branches.

Normal half-standard

Half-standard trees, pruned as above but not treated with IBA, were included as controls.

Results

Tree size

A single application of IBA to the cut end of the maiden half-standard tree had no visible effect on primary branch angle or tree size.

At 7 and at 9 years old, height and spread measurements were made on each tree and the cubic capacity of the head assessed. In making an estimate of the head size of standard trees, allowance was made for the distance between the base of the lowest branches and ground level. The unpruned trees soon became the largest, the pyramids the smallest, and the half-standards intermediate in size ; the difference between the unpruned trees and the rest being significant in the eighth year ($P<0.01$). Although the relative positions of the tree forms as regards size were retained, marked differences in shape visible at 6 years (Figs. 1, 2, and 3) had become less obvious at 8 years (Table I).

TABLE I

TREE SIZE AT 8 YEARS

	Unpruned	Pyramid	Half-standard
Head capacity (cu. m.)	65	38	43
Height (m)	3·8	3·4	4·0
Spread (m)	4·2	3·3	3·8

Yield

Although continually tested in the analyses of the data, no difference between half-standard trees with and without growth substance was apparent for yield or fruit size. All half-standard trees were therefore grouped as one treatment.

Up to the eighth year the unpruned trees yielded the heaviest crops but they were equalled by the half-standards in the ninth year, the only significant difference in that year being between pyramids and half-standards ($P<0.05$, Table II). On the whole, the yield of the pyramid trees was the lightest, except in the seventh year, when it was about the same as for the half-standards.

TABLE II

YIELD AND FRUIT SIZE

	Unpruned	Pyramid	Half-standard
Yield per tree in the ninth year (lb)	148	120	161
Fruit size in the ninth year (No. in 2 lb sample) ..	30	31	34
Total yield per tree at 9 years old (lb)	267	181	249
Yield in relation to tree size. (Yield in the ninth year ÷ head capacity)	2·3	3·2	3·7

A heavy fruit drop followed a severe frost on 27th May 1961, when the trees were nine years old. In spite of this reduction in number of fruits, and a further reduction in the size of many of those that remained owing to damage to the embryo, most trees yielded over a hundredweight of plums (Table II). The tendency shown in the ninth year for fruits from the half-standards to be rather small may be associated with the high yield in relation to size of head and thus presumably to leaf area (Table II).

Branch breakage and missing trees

The main periods of branch breakage occurred when the crop was on the trees in the seventh and ninth years. The standard and unpruned trees suffered a considerable amount of damage, whereas the pyramid trees were virtually free from it (Table III). The reasons for this different reaction are not altogether clear. The pyramid trees were only about half a metre shorter than the standards at the time of a gale (force 8 on the Beaufort scale) on 8th August 1961, and so it would appear that factors other than tree height were operative. Pruning, for example, may have had a considerable effect on branch length/diameter relationships. Knight (3) and Maggs (4) have shown that a reduction in the length of shoots by pruning is not followed by an equivalent reduction in thickening. Leader-tipped branches would therefore be thicker in relation to their length than those left to grow naturally. The lighter yield of the pyramids may also be taken into account, although this may not be an important factor since yield in relation to tree size was not very different from that of the half-standards (Table II). The fruits were, however, situated at points nearer to the centre of the tree instead of hanging out on

Victoria plum on Brompton rootstock

Fig. 1
Unpruned tree at six years old

Fig. 2
Pyramid at six years

FIG. 3
Half-standard at six years

Victoria plum on Brompton rootstock

FIG. 4
Half-standard at nine years. A branch that has snapped off under the weight of fruit is visible on the right

long, pendulous branches. The position of the branch bifurcations may also have had a bearing on proneness to branch breakage. In the half-standard and unpruned trees, the damage occurred, not at the junctions of primary branches with the trunk, but at bifurcations situated two to three feet away from the crotch (Fig. 4). In the summer pruned trees, division of the branches—where it occurred—was closer to the trunk.

TABLE III

BRANCH BREAKAGE AND MISSING TREES

	Unpruned	Pyramid	Half-standard
Weight broken branches in the ninth year (lb/tree)	3·3	0·1	6·0
No. missing trees at 9 years	2	3	4

Infection with silver leaf, *Stereum purpureum*, frequently followed wounding by branch breakage. Three unpruned and three half-standard trees were severely affected by this disease and only one of the pyramids showed any sign of it.

Two unpruned trees were removed in the course of the trial (Table III), one on account of severe silver leaf and the other because it became infected with bacterial canker, *Pseudomonas mors-prunorum*, following injury from a tree stake. The other missing trees were removed on account of bacterial canker, mainly following tractor damage to the trunk while the trees were still quite young. The pyramids affected by bacterial canker, for example, all died within two years of the date of the first summer pruning, before the treatment had had time to have much effect on the shape of the trees or on their metabolism. No losses of pyramid trees have occurred since that time.

Discussion

Both the unpruned trees and the summer-pruned pyramids have shown sufficient promise, compared with the half-standards for a more comprehensive trial of these tree forms to be initiated. The present series will, in addition, be continued for several more seasons.

The advantages of the unpruned tree over the commonly used standard tree-form include the following : it produced a large leaf- and fruit-bearing surface making full use of the allotted ground space ; both yield and fruit size slightly exceeded those of the standard ; the trunk, like that of the pyramid, is surrounded with laterals and branches of varying ages, and is protected from cultivation implements which might damage the bark and provide a means of entry for disease. Such damage occurred to several of the unprotected trunks of the half-standard trees.

The main advantages of the pyramid form were its resistance to branch breakage, and its smaller size. The size of 9-year-old pyramid trees on Brompton suggests that 12 ft apart in the row would be a suitable spacing. With a more dwarfing rootstock, St. Julien A for example, an even closer planting distance might be practicable. The use of labour for pruning in July when it may be in short supply is, of course, a disadvantage. If, however, early indications of increased fruit size and greater branch strength in the pyramids, are confirmed, the work of pruning in July may be offset by reduced labour requirements in June for thinning, and in August for shoring up branches. In addition, once the tree shape has been formed, it is possible that the time taken in summer pruning might be lessened by the use of an electrically-operated hedge trimmer, but experience in this matter is needed before any recommendation could be made. At present no commercial experience of pyramid plums appears to exist—but this restricted tree form would be well worth while in the private fruit garden and if, as the trees age and the weight of fruit increases, branch breakage continues at a very low level compared with other tree forms, it might be worth a trial in commercial orchards.

Summary

The behaviour, during the first nine years, of completely unpruned trees, and of summer-pruned pyramids of Victoria plum on Brompton rootstock is compared with that of half-standard trees. The pruning methods used in building up the different tree forms are described. Data for tree size, yield, branch breakage, and the incidence of disease are given and discussed.

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STEMBUILDER TRIALS WITH PLUMS

By ELIZABETH M. GLENN

In March 1936 two trials were planted to investigate the control of bacterial canker in plums, by (*a*) the use of resistant stems, (*b*) pruning at a ' safe ' time of year, and (*c*) spraying. The scion variety was Victoria, chosen because of its susceptibility to bacterial canker.

The details of raising the trees and the layout of the two trials have been described by Montgomery, Moore and Hoblyn (1943), who also described the effects of the various treatments on the incidence of bacterial canker, and the growth and cropping of the trees up to 1942.

In view of the renewed interest in the use of stembuilders for plums, and the recommendation to high work susceptible plum varieties onto resistant stems, some of the results on tree size and cropping in these two trials are worth further examination.

The first trial included five varieties as stembuilders, all on Myrobalan B roots. The most interesting trees were those with Myrobalan B stems (the most promising resistant stem), and those with Victoria stems. Trees with Myrobalan B stems were of two types ; in one the rootstock was run up to form the stem, and in the other the rootstock was budded at 6 in. with Myrobalan B, in the same way as the other stembuilder vareties. All trees were staddle worked with Victoria scions and half of them were pruned in winter and half in May.

In the early years the trees with Myrobalan B stems were slightly less vigorous than some of the others. This was explained by the check they received at planting, when the Myrobalan stems were in full leaf (Montgomery, Moore and Hoblyn, 1943). Subsequent growth levelled out this difference.

Table I shows heights and spreads of trees with Victoria stems and the two types of Myrobalan B (MB) stems. In effect this is a comparison between Victoria low worked and high worked on Myrobalan B. There were no significant differences in tree size.

TABLE I

TREE HEIGHT AND SPREAD IN DECIMETRES (TRIAL 1)

Type of tree	8-yr.-old heads		16-yr.-old heads	
	height	spread	height	spread
Victoria/Victoria/MB	45	45	53	49
Victoria/MB/MB/ (worked)	45	45	55	52
Victoria/MB/MB (unworked)	46	45	54	53

Table II shows tree size as measured by trunk girth, and cumulative crops. Again there were no significant differences between the three types of trees.

TABLE II

TREES WITH 13-YEAR-OLD HEADS. TRUNK AREA OF CROSS-SECTION AND CUMULATIVE CROPS (TRIAL 1)

Type of tree	Cross-section of stem (sq cm)		Cumulative crop (lb)	
	Winter-pruned	May-pruned	Winter-pruned	May-pruned
Victoria/Victoria/MB	198	185	463	468
Victoria/MB/MB (worked)	205	183	478	484
Victoria/MB/MB (unworked)	198	188	493	484
Mean	*200**	*185**	*478*	*479*

* Differ significantly at 1% level.

Pruning, after the first few years, consisted of removal of unwanted and broken branches only. In the early years May pruning, when the trees were in leaf, checked the vigour and increased cropping. By the time the trees were 13 years old there were no differences in cropping between the two treatments, but the May-pruned trees were still slightly smaller than the winter-pruned ones (Table II).

The second trial included Victoria staddle worked on Victoria stems on Myrobalan B roots, on Pershore stems on Myrobalan B roots, and on Pershore stems on Pershore roots. All the trees were pruned in May.

Differences in tree size and cropping between trees with Victoria and with Pershore stems, on Myrobalan B roots, were not significant, but trees on Pershore roots were significantly smaller and lighter cropping than those on Myrobalan B roots (Table III and IV).

TABLE III

TREE HEIGHT AND SPREAD IN DECIMETRES (TRIAL 2)

Type of tree	8-yr.-old heads		16-yr.-old heads	
	height	spread	height	spread
Victoria/Victoria/Myrobalan B.	44	42	56	50
Victoria/Pershore/Myrobalan B.	46	44	59	52
Victoria/Pershore/Pershore	41	39	53	45

TABLE IV

TREES WITH 13-YEAR-OLD HEADS. TRUNK AREA OF CROSS-SECTION AND CUMULATIVE CROPS (TRIAL 2)

Type of tree	Cross-section of stem (sq cm)	Cumulative crop (lb)
Victoria/Victoria/Myrobalan B	187	649
Victoria/Pershore/Myrobalan B	226	607
Victoria/Pershore/Pershore	151	455

Conclusions

In the first trial Victoria on Myrobalan B made the same sized tree, bearing the same amount of crop, whether the stem and crotch was formed by the scion variety or by the rootstock. Thus highworking the susceptible variety onto Myrobalan B gave resistance to bacterial canker without loss of crop.

In the second trial, trees on Pershore roots were smaller and lighter cropping than those on Myrobalan B; this is in accord with results from other plum rootstock trials (Glenn, 1961). However, the inclusion of a stem and crotch of Pershore between the scion variety Victoria and the vigorous rootstock Myrobalan B had no effect on tree size or cropping.

Summary

Tree size and cropping of Victoria on Myrobalan B were the same regardless of whether the stem and crotch was formed by the scion variety or by the rootstock. The inclusion of a stem and crotch of Pershore between the Victoria scion and Myrobalan B rootstock had no effect on tree size and cropping.

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THE BEHAVIOUR OF FOURTEEN CLONAL APPLE ROOTSTOCKS IN AN EXPOSED HILL-TOP ORCHARD

By A. P. PRESTON

Four main rootstock trials were planted at East Malling in 1945 to compare the performance of the new Malling-Merton clones with some of the older Malling rootstocks (2). After these trials had been planted sufficient additional trees on some rootstocks remained for two trials to be planted on a grower's farm at a considerably higher elevation providing an interesting contrast to the climate and soil of the main trials. This report describes the growth and cropping of trees on 14 rootstocks during the first 15 years on this site.

Site and plot layout

Newlands farm is 493 ft above sea level, on the North Downs in Kent. The soil overlies chalk and is of the Rattle Series, of clay-loam texture with numerous flints.

Three scion varieties were used, Cox's Orange Pippin, Jonathan and Ellison's Orange. Trial A comprised the three scions on MM.101, MM.104, MM.106, M.IV, and two rootstocks raised at the same time as the Malling-Merton clones, seedlings 96 and 829. Trial B included the same scions on MM.107, MM.108, MM.109, MM.110, MM.111, MM.115, seedling 411 and the New Zealand rootstock Ivory's Double Vigour (I.D.V.). The trees in Trial B are regarded as permanent and are interplanted with ' filler ' trees which form Trial A. Each trial contained three trees of each variety on each rootstock, distributed singly in three randomized blocks.

The trees were planted as maidens during the winter of 1945-46 and they have been pruned lightly by the regulated method, leader tipping being discontinued after the third year from budding (1). The permanent trees were spaced at 25½ ft square with a ' filler ' tree in the centre. The plot was clean cultivated during the first two seasons and in the autumn of 1947 wild white clover was sown, eventually giving a sward of clover and indigenous grasses which has since been close mown. After 10 years it was necessary to cut back severely the Ellison trees, which were the largest of the three varieties, to allow the passage of machinery through the plot; thereafter records from trees of this variety were excluded from the trial.

Results

Analysis of the data showed that there were considerable interactions between scion variety and rootstock, it would therefore be misleading to show a mean figure for all scions on each rootstock for trunk girth, crop, etc., so the mean values for each rootstock/scion combination are shown separately in the tables.

Owing to the absence of a rootstock common to both trials it is not possible to compare statistically the performance of any two rootstocks in different trials.

Trunk girth

The trunk girth data were transformed to logarithms for the analysis of variance, significant differences between the log girth of two rootstocks being expressed as significant ratios when the data are transformed back to actual girths (Table I).

In Trial A trees of Cox and Ellison on MM.104 were larger at 10 years than those on MM.106 but trees of Jonathan were smaller, and these differences also occurred with Cox and Jonathan at 15 years. Compared with trees on M.IV those on MM.104 were similar in size at 10 years but at 15 years Jonathan had made a slightly larger tree on M.IV and Cox a smaller one. Unlike Jonathan, Cox and Ellison both made relatively small trees on 829, their performance being comparable to that at East Malling where these varieties have made unthrifty trees on this rootstock. Trees on MM.101 were similar in size to those on MM.106.

In Trial B MM.109 and MM.115 made the largest trees at 15 years but at 10 years trees of Ellison on 411 were larger than those on other rootstocks. Trees on MM.110 were generally similar in size to those on MM.111, but Cox on MM.110 had made a larger tree by 15 years. There are several other stock/scion interactions, for example, Ivory's Double Vigour made a large tree with Ellison but a relatively small one with Cox and Jonathan, whereas MM.107 made small trees with Ellison and Jonathan but a fairly large one with Cox.

TABLE I

MEAN TRUNK GIRTH (CM) AT 10 AND 15 YEARS

	Trial A						Mean	Sig. ratio within a variety
10 years	MM.101	MM.104	MM.106	M.IV	96	829		
Jonathan	29·2	25·2	27·1	25·6	31·0	28·0	27·6	1·20
Cox	27·9	32·0	29·9	27·2	30·5	24·0	28·4	
Ellison	28·8	32·2	27·7	32·3	28·8	22·0	28·4	
15 years								
Jonathan	41·7	35·8	38·3	37·5	43·2	40·9	39·4	1·16
Cox	39·0	46·5	44·1	40·6	45·4	38·1	42·2	

	Trial B									
10 years	MM.107	MM.108	MM.109	MM.110	MM.111	MM.115	I.D.V.	411		
Jonathan	25·7	24·8	31·0	24·6	26·7	32·1	28·5	27·9	27·5	1·14
Cox	27·2	23·8	32·2	26·1	24·3	31·8	24·5	28·8	27·2	
Ellison	25·1	24·8	30·1	28·1	27·3	31·1	30·5	32·5	28·6	
15 years										
Jonathan	38·7	36·4	43·8	34·4	38·7	46·9	43·0	41·5	40·3	1·10
Cox	46·0	37·9	48·1	42·3	37·9	48·6	39·4	45·1	43·0	

Tree height and spread

Differences in height in Trial A when the trees were 15 years old were not significant. In Trial B, trees on MM.109, MM.115 and I.D.V. were the tallest, those on MM.107, MM.108, MM.111 and 411 were all of similar height (Table II).

TABLE II

MEAN TREE HEIGHT (M) AT 15 YEARS

	Trial A						Mean	Sig. diff. within a variety
	MM.101	MM.104	MM.106	M.IV	96	829		
Jonathan	3·2	3·0	3·0	3·2	3·5	3·3	3·2	ns.
Cox	3·2	3·7	3·4	3·1	3·3	3·3	3·3	

	Trial B									
	MM.107	MM.108	MM.109	MM.110	MM.111	MM.115	I.D.V.	411		
Jonathan	3·5	3·5	3·9	3·1	3·6	3·8	3·7	3·5	3·6	0·429
Cox	3·7	3·8	3·8	3·8	3·5	4·0	3·8	3·6	3·8	

Measurements of tree spread showed that in Trial A there was a significant interaction between rootstocks and varieties. With Cox, trees on MM.101 were the least spreading but with Jonathan they were the most spreading (Table III). Within each variety, trees on MM.104, MM.106 and M.IV all had a similar spread. In Trial B, however, rootstocks did not differ significantly, neither was there an interaction between rootstocks and varieties.

Total crop

The crops from trees of Jonathan on some rootstocks were inadvertently bulked in 1955, so the crop data for this variety and also for Cox and Ellison for this year have been omitted from the summary and analysis of variance.

At 10 years the yields from trees of Jonathan and Ellison were very similar and both were much heavier than those from Cox, and at 15 years the yields from trees of Jonathan were nearly twice as heavy as those from Cox.

In Trial A trees of Jonathan at 10 years yielded heavily on 96 and MM.106, but the yields from

TABLE III

MEAN TREE SPREAD (M) AT 15 YEARS

	Trial A						Mean	Sig. diff. within a variety
	MM.101	MM.104	MM.106	M.IV	96	829		
Jonathan	4·5	3·8	4·0	4·2	4·3	4·4	4·2	0·548
Cox	4·0	4·5	4·9	4·9	4·7	4·7	4·6	

	Trial B									
	MM.107	MM.108	MM.109	MM.110	MM.111	MM.115	I.D.V.	411		
Jonathan	4·2	3·8	4·0	4·1	4·3	4·6	4·1	4·2	4·2	n.s.
Cox	5·0	4·3	4·8	4·6	4·1	5·0	4·8	5·0	4·7	

trees on 829 were poor (Table IV). Cox on MM.106 and MM.104 cropped well ; trees on MM.101 and 829 were disappointing. Ellison on MM.104 and MM.106 cropped as well as trees on 96 and MM.101. At 15 years Jonathan on 96, MM.101, MM.106 and M.IV were the heaviest cropping trees with no significant difference between them. With Cox, although trees on MM.104 gave the heaviest crop, yields from trees on MM.106, 96 and M.IV were not significantly less.

In Trial B the crops from all varieties on MM.109 were outstanding at both 10 and 15 years.

TABLE IV

CUMULATIVE CROP (LB) AT 10 AND 15 YEARS

	Trial A						Mean	Sig. diff. within a variety
10 years	MM.101	MM.104	MM.106	M.IV	96	829		
Jonathan	262	272	307	281	342	129	266	94·52
Cox	86	217	221	156	174	37	148	
Ellison	313	266	277	238	339	236	278	
15 years								
Jonathan	835	680	820	809	970	738	908	191·83
Cox	319	607	583	448	528	233	444	

	Trial B									
10 years	MM.107	MM.108	MM.109	MM.110	MM.111	MM.115	I.D.V.	411		
Jonathan	148	203	273	243	236	255	182	255	219	65·85
Cox	72	36	160	77	98	89	40	118	86	
Ellison	170	93	349	279	199	203	163	299	224	
15 years										
Jonathan	615	628	866	726	696	802	747	851	741	136·01
Cox	218	193	565	418	416	369	328	449	369	

Of the several interactions between rootstocks and varieties, perhaps the most important one concerns Cox and Jonathan on MM.104 over the 15 year period. Trees of Cox on this rootstock gave the heaviest total crop whereas Jonathan trees yielded least. In the East Malling trials, which are also the same age, comparing the same range of rootstocks both Jonathan and Cox yielded heavily on MM.104. When the total crops are considered in relation to tree size, by expressing them per unit area of trunk cross-section, the performance of Jonathan on MM.104 is very similar to that for trees on MM.106 and M.IV (Table V), so it appears that the low crop is due to the relatively small size of the trees of Jonathan on MM.104. At East Malling this variety on MM.104 has made larger trees than those on MM.101, MM.106, M.IV and 829.

Discussion

Two interesting features of this site are the lessened risk of late spring frosts and the increased risk of wind damage compared with the average orchard at lower elevations ; the latter was largely over-

TABLE V

TOTAL CROP PER UNIT AREA OF TRUNK CROSS-SECTION AT 15 YEARS

Trial A				Trial B			
Jonathan		Cox		Jonathan		Cox	
829	5·5	829	2·0	MM.115	4·6	MM.107	1·3
MM.101	6·0	MM.101	2·6	I.D.V.	5·1	MM.108	1·7
96	6·5	96	3·2	MM.107	5·2	MM.115	2·0
MM.104	6·7	M.IV	3·4	MM.109	5·7	I.D.V.	2·7
MM.106	7·0	MM.104	3·5	MM.111	5·8	411	2·8
M.IV	7·2	MM.106	3·8	MM.108	5·9	MM.110	2·9
				411	6·2	MM.109	3·1
				MM.110	7·7	MM.111	3·6

come by the interplanting of permanent trees with fillers in this and other experimental plots on the farm (3, 4). These rootstock trials have indicated that Cox, even where densely planted, may not be one of the best cropping varieties to grow in such an exposed position, the yields from Jonathan and Ellison having been much heavier. In this respect an interesting comparison may be made between the yields up to 15 years in these trials and those in the East Malling trials, which are of the same age and on the same range of rootstocks. The average yield from trees of Cox at East Malling was more than twice as much as that from Newlands farm, but the average yield of Jonathan was almost exactly the same at the two sites. However, on rootstocks MM.101, MM.106, MM.110, M.IV, 411 and 829, the yield of Jonathan at Newlands was 23% greater than at East Malling.

The results from these trials over 15 years suggest that, of the rootstocks available for commercial planting, permanent trees on MM.109 or MM.104 interplanted with filler trees on MM.106 might be suitable for planting in similar exposed sites. However, MM.109 is a very vigorous rootstock and unless adequate spacing is given, fillers on MM.106 might have to be drastically cut back within 10 or 12 years from planting to allow the passage of machinery. Alternatively, permanent trees on MM.111 will not grow as large as those on MM.109 thus enabling the filler trees to remain intact for a longer period.

It should be noted that on some other sites, trees on MM.104 and MM.109 have been found to suffer damage from severe waterlogging, while those on MM.106 and MM.111 were less affected. No such damage was found among any trees in the present trials, in which the soil overlies porous chalk.

Acknowledgements

These trials were established through the co-operation of the owners of the farm, Newlands Fruit Ltd., and of their resident manager, Mr. J. Cronk. The Statistics Section assisted in planning the trials and carried out the analyses of variance. The help of these collaborators is gratefully acknowledged.

Summary

The growth and cropping of Jonathan and Cox's Orange Pippin on 14 clonal apple rootstocks during the first 15 years are reported together with results for Ellison's Orange during the first 10 years. The rootstocks were MM.101, 104, 106, 107, 108, 109, 110, 111 and 115 ; three rootstocks raised at the same time as the MM. clones, 96, 829 and 411 ; and Ivory's Double Vigour and M.IV. Trees of Cox and Ellison grew and cropped well on the semi-dwarfing MM.106, the vigorous MM.111 and MM.104, and the very vigorous MM.109, but, surprisingly, trees of Jonathan on MM.104 grew less vigorously than those on MM.106 on this site. The results are discussed in relation to the special problems of exposure on this hill-top site.

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WEATHER CONDITIONS DURING 1961

By G. F. TROWELL

East Malling Research Station

Following an exceptionally wet year, 1961 was in contrast a dry one. Temperatures generally were above average, especially during the first four months when very mild conditions were experienced. No frosts were recorded during April, but serious late frosts in May caused damage. Despite the total sunshine for December being a record, a cold spell throughout the latter half of the month brought temperatures rapidly down, with the only snow fall of the year falling appropriately on the last day of 1961.

The total rainfall during the year was 24·66 in., 2·03 in. below the 35-year average, and 11·29 in. less than in 1960. Rainfall remained high during January and February continuing on the same lines as the six previous months of 1960 ; in fact the total rainfall during July 1960 to February 1961 inclusive was 31·75 in., over 12 in. above the average for this 8-month period, with rain falling on 170 days out of the 243. Rainfall was below average during March, May, July, August, September, and November. March was the driest month of the year, with 0·03 in. of rain falling on only 2 days, and was the driest March since 1929, when 0·02 in. of rain fell. The distribution of rain during May and June was somewhat irregular ; most of the 0·96 in. recorded in May fell during the first week, and of the 1·75 in. of rain during June, 1·17 in. fell on 12th, the heaviest day's rainfall of the year. August on the other hand had only 1·04 in. recorded, but rain fell on as many as 15 days with traces of rain on 8 other occasions. During most of the spring and summer months rainfall was below average, in fact only 8·96 in. of rain fell during March to September inclusive, 4·81 in. below average. But after this fairly long dry spell, rainfall increased considerably in October (the wettest month of the year), with 4·12 in. The longest wet periods of the year were between 31st January and 8th February, and 6th and 14th November, with the longest dry period between 8th and 26th May. Rain fell on 165 days throughout the year as compared with 212 in 1960.

Mean air temperatures were all above the seasonal average except during May, July and December. They were the highest during February and April since 1945 and 1949 respectively, but were the lowest in December since 1952. Mean maximum temperatures generally were above average, but below average during May, July, November, and December. Maximum temperatures during March were the highest since 1938. The highest screen temperature during 1961 was 92° F, recorded on 1st July, the hottest July day since 1921, equalling the highest temperature ever recorded at East Malling. The 87° F recorded on 29th August was the highest temperature for this month since 1953, when 88° F was reached. Mean minimum temperatures were above average during January to April inclusive and August to October inclusive. They were the highest in February and April since 1945 and 1943 respectively. The lowest screen temperature recorded during February was 30° F, the highest screen minimum for this month since 1937, and the lowest temperature during April, 35° F, was the highest minimum for April since observations began in August, 1914. The lowest screen minimum of the year was not reached until late December, when 16° F was recorded on Christmas Day, the lowest figure for December since 1946.

Sunshine during the year amounted to 1,686·0 hours, 123 hours above the 25 year average, and 204·8 hours above last year's total. Sunshine was above average during January, March, May, June, October, November, and December. It is interesting to note that only February showed a deficit during the winter months, and only then by an extremely small amount (Table I). The total sunshine during March was 177·4 hours, the sunniest since 1938, when 196·7 hours were measured. April on the other hand was the dullest since 1941, with 44 hours below average. June was the sunniest month of the year with 250·7 hours, 28·7 hours above average. Despite November and December each having 13 days on which no sunshine was recorded, they were both extremely sunny. November with 72·5 hours was the sunniest since 1949, while December sets up another record for 1961, as the sunniest December since records began, with 81·4 hours sunshine, almost twice the average (previous sunniest was 63·3 hours in 1929). The sunniest day of the year was on 25th June when 14·7 hours sunshine were measured. There were 52 days throughout the year when no sunshine was recorded, 26 less than in 1960.

Ground frosts were fewer than in recent years (69 compared with 77 in 1960, and 78 in 1959), the lowest number since 1953. No air or ground frosts were experienced in April for the first time since records began ; the previous lowest was one in 1937, with no frosts during the following May of that year. In contrast to this, in 1961 extremely late frosts were experienced on the 28th and 29th

Table I

SUMMARY OF METEOROLOGICAL OBSERVATIONS DURING 1961

East Malling

Month	Temperature in Screen (°F)					Number of Frosts		Rainfall (in.)				Sunshine (hours)			Soil Temperature (°F)			
	Mean maximum	Mean minimum	Mean	Highest	Lowest	Air *	Ground †	Total	35 years' average	Heaviest fall in a day	Number of days 0·01 in. and over	Total	Average per day	25 years' average	4 inches	8 inches	2 feet	4 feet
January	44·4	34·0	39·2	52	25	14	16	3·44	2·46	1·00	16	54·8	1·77	47	36·0	37·6	39·6	42·4
February	50·9	38·7	44·8	62	30	3	5	2·09	1·95	0·70	19	67·4	2·41	68	42·0	42·4	43·1	43·5
March	57·0	36·1	46·6	70	24	9	12	0·03	1·57	0·02	2	177·4	5·72	123	43·3	43·7	45·4	45·5
April	58·9	42·9	50·9	65	35	0	0	1·90	1·90	0·31	18	108·2	3·61	152	52·5	50·4	50·5	48·6
May	61·7	42·5	52·1	75	30	2	3	0·96	1·93	0·47	10	232·2	7·49	200	56·6	54·3	54·6	52·5
June	70·4	47·3	58·9	85	37	0	0	1·75	1·63	1·17	8	250·7	8·36	222	64·6	61·0	60·2	56·2
July	71·0	50·9	61·0	92	40	0	0	1·22	2·25	0·36	11	197·6	6·37	208	65·2	63·6	64·0	60·6
August	70·6	52·5	61·6	87	42	0	0	1·04	2·31	0·27	15	180·4	5·82	194	63·1	62·0	62·8	60·7
September	69·6	51·6	60·6	83	39	0	0	2·06	2·18	0·49	16	130·8	4·36	147	61·0	60·4	61·9	60·4
October	60·6	44·0	52·3	71	31	1	2	4·12	2·85	1·07	17	132·6	4·28	105	50·9	51·9	55·1	57·0
November	49·6	37·5	43·6	63	24	11	12	2·60	3·18	0·79	18	72·5	2·42	55	42·0	43·4	46·7	50·6
December	44·5	31·4	38·0	59	16	20	19	3·45	2·48	0·51	15	81·4	2·63	42	36·5	38·1	41·4	45·6
Totals						60	69	24·66	26·69		165	1,686·0		1,563				
Mean	59·1	42·5	50·8												51·1	50·7	52·1	52·0

Sub-Station, Newlands Farm, Throwley

January	42·3	33·6	38·0	49	22	12	20	3·84		0·82	15	54·7	1·76		36·9	37·8	40·4	43·9
February	49·6	38·5	44·1	56	32	1	9	2·86		0·78	17	85·8	3·06		42·2	41·8	42·9	43·7
March	55·4	38·5	47·0	67	28	4	23	0·11		0·05	3	174·5	5·63		44·1	43·8	45·2	45·5
April	57·1	43·2	50·2	65	38	0	2	2·33		0·45	19	108·3	3·61		51·3	50·5	49·4	47·7
May	60·0	43·3	51·7	73	33	0	4	0·52		0·21	7	243·0	7·84		55·9	54·5	53·6	51·1
June	67·8	49·1	58·5	81	42	0	0	1·32		0·89	9	266·9	8·90		63·0	60·8	58·9	54·7
July	68·4	52·0	60·2	88	45	0	0	1·16		0·49	10	190·1	6·13		64·2	62·8	62·5	58·8
August	68·2	52·6	60·4	85	45	0	0	1·25		0·33	13	181·2	5·85		62·0	61·1	61·3	58·9
September	68·7	51·9	60·3	81	44	0	0	2·07		0·57	13	130·6	4·35		60·9	60·6	61·2	59·3
October	59·2	45·5	52·4	67	35	0	5	3·82		0·89	17	129·1	4·16		51·4	51·5	55·8	57·1
November	48·3	39·1	43·7	61	30	3	13	3·47		0·77	16	74·7	2·49		43·7	43·1	48·3	51·9
December	44·0	32·7	38·4	56	19	17	20	4·58		0·82	16	85·3	2·75		37·4	38·5	43·3	47·2
Totals						37	96	27·33			155	1,724·2						
Means	57·4	43·3	50·4												51·1	50·6	51·9	51·7

* Air Frost 32·0° F or below. † Ground Frost 30·4° F or below.

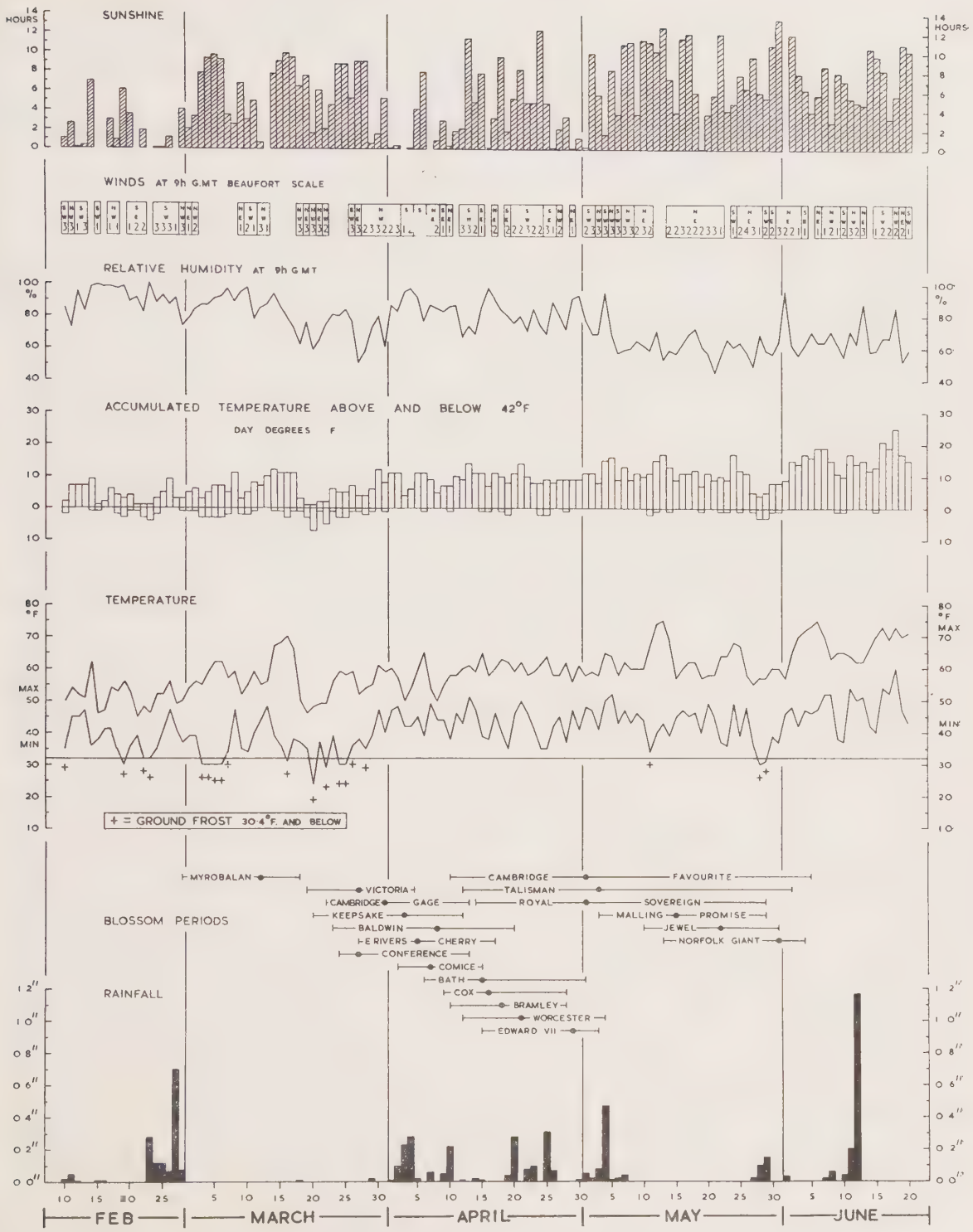

FIG. 1

Diagram showing weather recorded during the blossoming season at East Malling during 1961

May, when 30° F and 31° F were recorded in the air, with 26°F and 28° F on the ground. The 30° F on 28th May was the lowest air temperature recorded so late in the season, the previous lowest being 31° F on 29th May 1927, and 32° F on 31st May 1915 and 1957. Damage was caused by these late frosts during the past year, but far more serious damage might have been caused to top fruit, had it not been for the advanced stage of fruitlets due to the early season.

Blossoming started early with all varieties ; Myrobalan B was earlier than the average by 18 days, and later varieties by an even larger margin. Full bloom on Cox was some three weeks early, the earliest since 1945.

Pollination conditions were not good during the latter half of March but considered good throughout much of April, and during May, despite the fairly long spell of north-easterly winds (Fig. 1), conditions were moderately good.

Gusts of 40 m.p.h. were experienced on 4 occasions during 1961, on 6th February, 8th August, 19th October and 5th December. Strong winds of ' Force 6 ' and over occurred 35 times, once more than in 1960. Winds from a south-westerly direction were recorded on 119 days, compared with 122 in 1960 and 104 in 1959.

No snow fell until the last day of 1961, with approximately 4 in. of snow lying by the end of the day. One very slight sleet shower was recorded on 20th March. Hail was recorded on only 2 occasions, once each in October and November.

Thunderstorms were very infrequent, occurring only twice over or in the neighbourhood of the Station on 4th May and 17th October. Distant thunder and lightning was recorded on 3 other occasions. Fog was experienced 33 times, the foggiest month being September.

The ground remained very wet throughout January and February, due to the large quantity of rain that fell during the latter half of 1960. The ground was frozen on very few occasions during the 1960 to 1961 winter months, in fact frozen ground was recorded 8 times in January, and on only 11 days between February 1960 and November 1961, all to a depth of less than 2 in. Ground conditions in March were somewhat the reverse, dry ground being recorded on 23 consecutive days, and these dry conditions were again experienced throughout much of the summer. Wet ground was recorded during the latter half of September and throughout October. The ground was frozen 18 times during December, 13 of which were continuous, the greatest depth being 6 in.

Newlands Farm, Throwley

Total rainfall at this sub-station was 27·33 in., 2·67 in. more than at East Malling, the difference being considerably less than in recent years. Dry conditions were also experienced at Throwley during March, the driest month of the year, 0·11 in. falling on 3 occasions. December was the wettest month with 4·58 in. of rain. The heaviest days' rainfalls of the year were on 12th June and 24th October with 0·89 in. of rain. Rain fell on 155 days during 1961, 10 less than at East Malling.

Mean air and maximum temperatures were about the same or below those at East Malling, while the mean minima were generally above. The highest temperature of the year was 88° F recorded on 1st July, and the lowest screen temperature 19° F on 25th December, both extremes occurring on the same dates as those at East Malling.

Total sunshine at this sub-station was above that at East Malling by 38·2 hours. June was the sunniest month with 266·9 hours. The sunniest day of the year was on 25th June when 15·5 hours sunshine were measured.

Ground frosts were more numerous than at East Malling, 96 compared with 69. It is interesting to note that only 37 air frosts were recorded at Throwley as compared with 60 at East Malling. (Table I.)

Snow and sleet fell 10 times during January, February, March, and December, falling as showers on all occasions, except when snow fell continuously on 31st December. Hail was recorded only once during 1961.

Gale force winds were experienced 21 times during January, May, July, August, October, November, and December. Thunder was recorded 4 times.

Acknowledgements

The author wishes to thank Mr. C. H. W. Slater for his assistance during the year. Mr. J. Cronk (by courtesy of Sir Thomas Neame) was responsible for records at Newlands Farm, and his co-operation is gratefully acknowledged.

Corrigendum

The total rainfall at East Malling during August 1943, as published in the 1943 Annual Report has been found to be incorrect, it should read 1·37 in. of rain, with 24·31 in. the total rainfall for 1943. This slightly reduces the 35-year average, by 0·04 in. August now reads 2·31 in. with the total rainfall 26·69 in.

PLANT PHYSIOLOGY

THE INFLUENCE OF THE LEAF UPON THE DEVELOPMENT OF ITS AXILLARY MERISTEM

By H. W. B. BARLOW and the late C. R. HANCOCK

A previous paper (Barlow and Hancock, 1960) has described how the position of the bud on the shoot affects the foliar structures displayed on branches induced to extend during the current year's growth. Branches induced by decapitating the shoot at lower levels showed a series of bud scales merging by transitional forms into normal leaves ; branches induced further up the shoot showed fewer transitional forms, and if induced to grow from very young regions, only a single pair of basal opposite foliar organs preceded a normal leaf. These basal bud scales may have a different origin from the others, and have been termed ' prophylls ' by some authors (see Foster, 1928). Branch induction by removal of very small leaves as they developed invariably produced organs with a crescentic lamina in place of the usual bud scale, but high decapitation induced branches at corresponding nodes which bore crescents and bud scales about equally.

It was suggested that although decapitation always induced at least the uppermost 2-3 buds to grow out, the presence of the subtending leaf slowed up the development of the axillary meristem just enough for the prophylls sometimes to be reduced to scales, or sometimes to develop into more leaf-like organs. The natural occurrence of crescents supports this view ; in vigorously growing nursery material, some varieties tend to produce branches concurrently with apical growth (the ' rameaux anticipés ' of Champagnat, 1954a and b) ; well-developed crescents are often displayed on the lower branches, but as the branches become weaker higher up the shoot, bud scales predominate. Again, in varieties which if untreated branch little, but which respond to defoliation or decapitation high up the axis, such treatments produce the greatest proportion of crescents under favourable growing conditions.

To test the hypothesis that the subtending leaf slows down the outgrowth of the axillary meristem and affects the form of the basal foliar organs, the two experiments described in this paper were carried out.

Materials and methods

As in previous work of this type, vigorously growing vegetative shoots of the apple rootstock variety Crab C were the test objects ; they grew on small very hard pruned ' treelets ' (not on stoolbeds as previously used). The leaf numbering system was as previously described (Barlow and Hancock, 1956a), the reference leaf +1 being that which was just completely flattened or with only the basal edge slightly inrolled, and about 30 mm long ; the leaves above this were numbered —1, —2, —3, *et seq.*, acropetally.

In the first experiment 120 shoots were decapitated above leaf —5, and 80 left intact ; in each lot either no leaves were removed, the single leaves —5, —4, —3 or —2, or the following groups of leaves : —5 and —4 ; —5, —4 and —3 ; —5, —4, —3 and —2. The extra number of decapitated shoots was intended to allow for failures in this rather difficult operation, but even so the number of successfully treated shoots varied from 7 to 15 per treatment.

The treatments were carried out on 22nd and 23rd June 1960 ; a record of shoot development and basal organs was made some 25 days later, and a final record 11 weeks after treatment.

In the second experiment, 160 shoots were all decapitated above leaf —5, and, in view of the results of the first one, all 16 groupings of the top four leaves were removed, i.e. —5, —4, —3 and —2 singly, in pairs, threes, or all four. These treatments were carried out on 29th July 1961, and records made at intervals.

Results

Table I summarizes the effects of the 1960 treatments on the proportion of shoots which produced branches in the treated zone ; the record taken about three weeks after treatment gives a rough indication of the rate of bud growth when compared with the final result.

TABLE I

PERCENTAGE OF POSSIBLE BUDS DEVELOPING AFTER (a) 25 DAYS (b) 11 WEEKS FROM TREATMENT

Intact shoot								Shoot decapitated above −5							
−2		−3		−4		−5		−2		−3		−4		−5	
a	b	a	b	a	b	a	b	a	b	a	b	a	b	a	b
0	0	0	0	0	0	0	0	0	0	27	45	36	100	36	100
20	20	10	10	0	0	**20**	**30**	44	44	44	56	56	100	**67**	**100**
20	20	0	0	**40**	**50**	0	0	27	36	45	55	**73**	**100**	45	100
0	0	**30**	**30**	0	0	0	10	31	31	**85**	**100**	31	85	23	100
56	**56**	0	0	0	0	0	0	**73**	**73**	27	33	40	87	47	100
11	11	0	0	**56**	**56**	**11**	**22**	43	43	57	71	**100**	**100**	**57**	**100**
10	10	**90**	**90**	**50**	**50**	**30**	**30**	67	78	**100**	**100**	**78**	**100**	**78**	**100**
89	**89**	**67**	**78**	**44**	**44**	**22**	**33**	**100**	**100**	**100**	**100**	**86**	**100**	**57**	**100**

Bold type indicates defoliated nodes.

Considering the intact shoots first, it will be evident that removing single leaves has stimulated some bud growth, predominantly at the defoliated node, and that removing more leaves caused more buds to grow out ; the lower nodes, −3 and −2, particularly benefited from the loss of the leaves above them at −4 and −5. This result led to the 1961 treatments, which attempted to clarify the effect of these upper leaves on the buds below them. It will be noticed that if branches were eventually formed at all, then the buds from which they sprang were active within 25 days of treatment—if stimulation had not occurred by then it apparently could not take place at all.

In the decapitated shoots a far greater proportion eventually developed axillary branches—all shoots at the top node, and most at the next—irrespective of leaf removal ; even there, however, removing either or both leaves accelerated the outgrowth of the buds. At the two lower nodes a high proportion of buds broke only when their subtending leaves were removed, or at node −3 when both leaves −4 and −5 were taken off, and at node −2 when all three leaves above were removed.

There was no consistent effect of leaf removal on final branch length ; decapitation of course led to much longer branches than defoliation.

The increased rate of development of the buds when the subtending leaf was removed, was reflected in the nature of the foliar structures at the base of the branches, as shown in Table II.

In the intact shoots crescents made up 50% or more of the organs at the base of the branch where the subtending leaf had been removed, but only once occurred on the few branches which grew in the presence of a leaf.

TABLE II

PERCENTAGE OF BASAL ORGANS REPRESENTED BY CRESCENTS

Intact shoot				Shoot decapitated above −5			
−2	−3	−4	−5	−2	−3	−4	−5
—	—	—	—	—	0	10	10
0	0	—	**66**	50	40	44	**94**
0	—	**60**	—	25	50	**91**	50
—	**50**	—	100	50	**62**	27	23
80	—	—	—	**59**	40	31	33
0	—	**100**	**50**	0	20	**100**	**100**
0	**72**	**60**	**83**	21	**72**	**78**	**100**
88	**93**	**88**	**83**	**93**	**100**	**100**	**100**

Bold type indicates defoliated nodes.

In the decapitated shoots there was a high proportion of crescents only where the subtending leaf was absent, although up to 50% could be formed even in its presence, contrasting with the situation in the intact shoots. Crescent formation on branches at foliated nodes −2 and −3 was not on the whole enhanced by removing leaves −4 and/or −5 (lower nodes averaged 30% crescents with

leaves either present or absent above them). Comparisons of the corresponding effect on defoliated lower nodes are limited to two treatments, and even they are not strictly valid ; for better assessment of the effect of various defoliation patterns on bud development the 1961 results must be considered.

In that experiment all shoots were decapitated above leaf −5, and a fortnight after treatment bud activity was pronounced at all defoliated nodes, and slight at those with leaves ; such as there was at leafy nodes was largely at node −5. After 27 days (about the same period from treatment as in 1960) many buds had grown and produced well-developed leaves and even a few short shoots. As an index of the rate of growth of these buds up till this stage, the total length was measured from the point of insertion of the bud on the main axis to the tip of the longest organ growing from the bud—this might be a bud scale, a crescent, or a leaf, but represented some measure of activity by the bud concerned. Where the bud had not broken zero length was assigned to it, because although it was some 3-5 mm in length it was often hidden by the petiole base. Table III gives these lengths, and beside them, the percentage of basal organs which were indubitably more than bud scales—usually crescents, but at least scales with a distinct appendage.

TABLE III

(a) BUD ACTIVITY 27 DAYS AFTER TREATMENT, MEASURED AS ' LENGTH ' (MM)
(b) PERCENTAGE OF BASAL ORGANS OTHER THAN SCALES

Treatment No.	Node							
	−2		−3		−4		−5	
	a	b	a	b	a	b	a	b
1	0	0	3	0	17	14	13	14
2	**27**	**30**	1	0	14	5	11	30
3	0	0	**25**	**40**	5	0	7	15
4	1	0	19	0	**40**	**100**	21	56
5	0	0	1	0	3	0	**14**	**59**
6	**34**	**50**	**41**	**80**	16	25	17	55
7	0	0	**38**	**82**	**33**	**100**	9	23
8	8	0	10	0	**30**	**89**	**16**	**72**
9	**45**	**28**	4	0	**37**	**91**	15	36
10	1	7	**52**	**100**	21	14	**24**	**100**
11	**31**	**0**	6	6	9	0	**18**	**50**
12	**60**	**75**	**55**	**90**	**36**	**85**	24	75
13	0	0	**40**	**86**	**29**	**100**	**17**	**72**
14	**35**	**13**	**48**	**75**	21	44	**16**	**50**
15	**53**	**63**	20	25	**29**	**75**	**20**	**81**
16	**38**	**40**	**51**	**60**	**33**	**90**	**19**	**80**

Bold type indicates defoliated nodes.

It is evident that there was a good deal of bud activity at node −5 whether that leaf was removed or not, but at the other nodes, where bud activity was greater, the effect of leaf removal was more pronounced :

Node		−2	−3	−4	−5
Bud length (mm.)	−leaf	40	44	33	18
	+leaf	1	8	13	15

The same trends were shown by the basal foliar structures on the putative branches, but leaf removal was even more effective in inducing crescent formation than in promoting bud growth :

Node		−2	−3	−4	−5
% 'non-scales'	−leaf	37	77	91	70
	+leaf	1	4	13	38

The correlation between early bud activity and the tendency of the basal foliar organs to be leafy, is shown by comparing the average lengths of all buds with given complements of scales, scales with appendages, or crescents, irrespective of node or treatment :

	Type of basal organ				
	Scale Scale	Scale Scale +	Scale+ Scale+	Scale+ Crescent	Crescent Crescent
'Length' (mm)	9·0	31·8	20·2	35·7	40·5
No. of observations	294	33	21	85	108

The 1961 treatments were designed primarily to assess the effect of leaves on bud growth at other nodes, particularly of the upper pair of leaves on the lower two buds. No effect was detectable 27 days after treatment, either on bud activity or organ form, and this state of affairs necessarily remained unaltered as far as the type of organs was concerned. Branch length a month later was not affected by the defoliation pattern either, but the effect of bud position changed between four and eight weeks from treatment ; at four weeks bud activity had increased from the top node downwards, but later the length of the branch (in this case the actual stem length) on the average decreased :

Node		−2	−3	−4	−5
Branch length (cm.)	− leaf	5·2	10·1	15·1	12·8
	+ leaf	0·1	2·9	7·6	12·2
	Average	2·6	6·5	11·4	12·5

The effect of leaf removal on branch length, as in the case of early bud activity, was negligible at the top node, but became more pronounced lower down.

Discussion

In dicotyledonous plants the axillary meristem usually forms a bud during the vegetative phase of growth, and in trees this tends to remain quiescent for some time. It may extend during the next season (or growth flush), may form a short shoot, or may remain dormant until specially stimulated. In fruit trees the immemorial practice of pruning relies on stimulation by removal of the shoot above.

This ' apical dominance ' from which such a bud is released is usually thought of as the factor which inhibits the outgrowth of these lateral buds after they have once been formed, but it might more logically be regarded as the factor which brings about the development of the bud from the axillary meristem in the first place.

Our studies of vegetative shoot growth in the apple suggest that the axillary meristem would immediately grow out as a branch bearing normal leaves if it were not inhibited by the main axis. This inhibitory influence resides in the young leaves at the apex, and results in the condensation of the lateral axis into a bud. It is tempting to think that the primary inhibition is on the development of the blades of the first few phyllomes on the lateral axis, and that just as removal of the small leaves on the main axis reduces internode length, so the absence of lamina on the lateral axis itself leads to the reduction of internodes in the typical bud.

When the lateral meristems are induced to develop immediately, by such treatments as described in this paper, they grow out as branches bearing normal leaves except at the extreme base, and it is impossible to say whether internode extension results from the presence of lamina, or whether both follow independently from the release from apical dominance. At the base of the branch, however, is a pair of opposite phyllomes (the prophylls) of which the degree of leafiness can vary from zero—the true bud scale—to a considerable laminar surface, albeit asymmetrical—the crescent. Whatever the amount of lamination these structures remain basal, so that at this site at least internode extension does not appear to be associated with the presence of lamina.

Of the early-formed parts of the branch not only do the basal organs vary in size on branches of different lengths, but so do the length of the first internode and the size of the first leaf. In view of the complex relationships found on the main axis between leaves at various stages of growth, and between leaves and internodes (e.g. Barlow and Hancock, 1956b), the following data on the lateral branches

were acquired, and the relations between them examined : *a*, the size of the basal organs, represented by their summed pair of lengths (mm) ; *b*, the length of the first internode (mm) ; *c*, the size of the first leaf, represented by the product of its length and width (cm²) ; *d*, the length of the branch eight weeks after treatment (cm).

The average values for all branches showed that removing the subtending leaf resulted in greater growth of all four entities, and the relations between them were therefore considered separately for the branches at defoliated and leafy nodes :

	a	*b*	*c*	*d*
at defoliated nodes	32·6	6·4	16·5	10·8
at leafy nodes	12·2	3·4	6·1	5·7

For both groups of branches highly significant positive correlations were found between all six pairs of measurements (ranging in value from 0·80 to 0·95), but they gave no indication of the most important associations, merely suggesting that conditions favouring large basal organs equally favoured long first internodes, large first leaves, and long branches.

TABLE IV

Correlation coefficients between : *a*, basal organ size ; *b*, first internode length ; *c*, first leaf size ; *d*, branch length.

D, branches at defoliated nodes ; L, branches at leafy nodes.

Correlated variables	Simple coefficients		First order partials, holding the indicated term constant								Second order partials	
			a		*b*		*c*		*d*			
	D	L	D	L	D	L	D	L	D	L	D	L
						'UNLIKE PAIRS'						
ab	·81***	·87***	—	—	—	—	·38*	·09	·36*	·57**	·25	·46*
bc	·85***	·91***	·55**	·53**	—	—	—	—	·38*	·41*	·28	−·17
cd	·86***	·90***	·60***	·71***	·49**	·29	—	—	—	—	·39*	·58**
ad	·81***	·80***	—	—	·36*	−·12	·36	−·31	—	—	·20	−·53*
						'LIKE PAIRS'						
ac	·82***	·95***	—	—	·42*	·75***	—	—	·40*	·85***	·30	·82***
bd	·87***	·95***	·63***	·84***	—	—	·52**	·70***	—	—	·44*	·77***

* P < ·05 ** P < ·01 *** P < ·001

A survey of the first and second order partial correlations (Table IV), however, showed :

(i) that holding *a* constant had little effect on correlations between the remaining entities, suggesting that basal organ size is not an important factor in relations between the other entities, and

(ii) that in correlations between ' unlike ' pairs of entities (e.g. basal organ size and first internode length, first leaf size and branch length, etc.) holding the other variates constant generally reduced the correlation appreciably, whereas for ' like ' entities there is not such a marked reduction. This implies a strong direct association between like entities, particularly between first internode length and branch length, irrespective of the values of the other variates, whereas the unlike entities would appear to be associated indirectly through the agency of a third variate (which in these data must of necessity be like one of the entities whose correlation is being considered).

The interrelations of the organs on the branch are undoubtedly very complex, and probably little real headway will be made in sorting them out until some of the underlying *causal* factors have been evaluated, such as the rates of supply to the meristems, internodes, and leaves, of growth substances controlling cell division, extension, and expansion.

In the region of the main axis which is just expanding from the terminal cluster of leaves the lateral meristems are evidently at a very critical stage in which their own foliar primordia are plastic ; with rapid development of the lateral axis even the basal primordia become leafy, but a short delay allows inhibition of their laminae to varying extents, and further delays result in blade reduction at additional nodes along the branch. Even when outgrowth of the meristem is assured by high decapitation, the presence of the subtending leaf slows down that growth, and suppresses the lamina of the basal phyllomes.

This role of the young leaf in controlling the fate of foliar primordia on the meristem in its axil, i.e. on bud formation as well as inhibition of the growth of buds already formed, is put forward for consideration at a time when concepts of growth control are widening, due to the recognition that as well as auxins, gibberellins, kinins, and inhibitors of various kinds must also be borne in mind, and when in particular the field of apical dominance is being re-explored (e.g. Wickson and Thimann, 1958).

Acknowledgements

The help of Mr. P. Sprent, of the Statistics Section, is gratefully acknowledged.

Summary

1. When lateral meristems are induced to grow out from very high up on the main axis by decapitation within the terminal leaf cluster, normal leaves occur at the first node of the branch.

2. At the extreme base of the branch is a pair of organs which may be typical bud scales or may show varying amounts of lamina, crescentic in shape. The presence of the subtending leaf favours scale formation and its absence crescent production.

3. The significance of these and earlier results is discussed in relation to the concept of apical dominance.

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THE VEGETATIVE GROWTH OF YOUNG PLANTS OF BROMPTON PLUM INFESTED WITH FRUIT TREE RED SPIDER MITES

By D. J. AVERY

Although several authors have reported harmful effects of infestations of fruit tree red spider mites on the growth and cropping of fruit trees, the evidence presented frequently appears to be largely subjective and surprisingly few experimental data have been given. Several workers have reviewed the literature related to this subject (2,3,4,5), and Van de Vrie (5) in Holland, and Boulanger (3) in the U.S.A. have both studied certain aspects of the damage caused by feeding mites.

In this paper the results are reported of the first experiment of a series designed to evaluate the importance of fruit tree red spider mite (*Metatetranychis ulmi* (Koch)) injury under English conditions.

Materials and methods

Small plants of Brompton plum which had been propagated from cuttings were grown in compost in clay pots arranged in the open in two adjacent groups of twelve plants each. On 9th May, after the buds had burst, all but the top two buds were removed so that each plant was restricted to two growing shoots.

All the plants were sprayed with TEPP on 25th and 27th May to ensure that no mites were present.

One group of twelve plants was inoculated with fruit tree red spider mites on the 30th May, by tying infested apple leaves at the bases of the two shoots. The mites walked on to the test plants and after a fortnight the apple leaves were removed, by which time eggs on them would have hatched. A further inoculation was given to the same plants in a similar manner on 3rd June by tying leaves to the middle of each shoot. In all, each shoot received an inoculum that included approximately 350 mites and 1,500 eggs.

Both the mite-infested and the control plants were sprayed with DDT on 21st June and 9th August when it was judged necessary to control the predatory insects without harming the mites inoculated on to the plants.

The plants in the control group were not inoculated, but in all other respects they were treated in the same way as the inoculated plants, and no attempt was made to protect them from mite infestation by additional sprays. Regular inspections showed that the control plants remained virtually free from mites until the end of the season.

Although it was recognized that the design of an experiment with only one group per treatment was not ideal, it was considered that the problems associated with the dispersal of mites from inoculated to control plants made a randomized lay-out impracticable. To overcome this possible weakness in design, the three weeks prior to inoculation were used as a calibration period during which the growth of the plants in the two groups was compared.

The measurements made on each plant included its fresh weight at potting, the fresh and dry weights of its parts at the end of the season, the diameters at three positions on the old stem at both the beginning and end of the season, and similar diameter measurements of the new shoots at the end of the season. At intervals throughout the season, the length of each shoot was measured. The production of new leaves was recorded by counting the number of leaves above a marked leaf on each shoot. All the marked leaves were labelled on the same day, each being four leaves below the youngest flattened one present on 17th May.

Results

The measurements of shoot length and production of leaves throughout the season are shown in Fig. 1. The two arrows on the abscissa indicate the dates of inoculation with mites. Up to the time of the first inoculation the curves for the two groups of plants were remarkably similar, indicating that the behaviour of both groups was essentially the same during the calibration period. Subsequent to inoculation the curves diverged, indicating a reduction in growth rate caused by the mites. The divergence between the mean length of all the shoots on the mite-infested plants and the mean shoot length of the control plants continued until the end of August. By 5th September the tips of the shoots of nearly all the plants in both treatments had abscissed naturally since the previous date of

measurement—a phenomenon often observed in Brompton—and by this date the mean shoot length of the mite-infested plants was only 82% of that of the controls.

Further examination of the shoot lengths revealed that there had been an interaction between the two shoots on each plant which differed in the two treatments. This had resulted in the two shoots on the mite-infested plants growing to similar lengths whereas the upper shoots on the controls generally exhibited considerably stronger growth than the lower ones. The data for the upper and lower shoots were therefore separated and corresponding measurements for the two treatments were

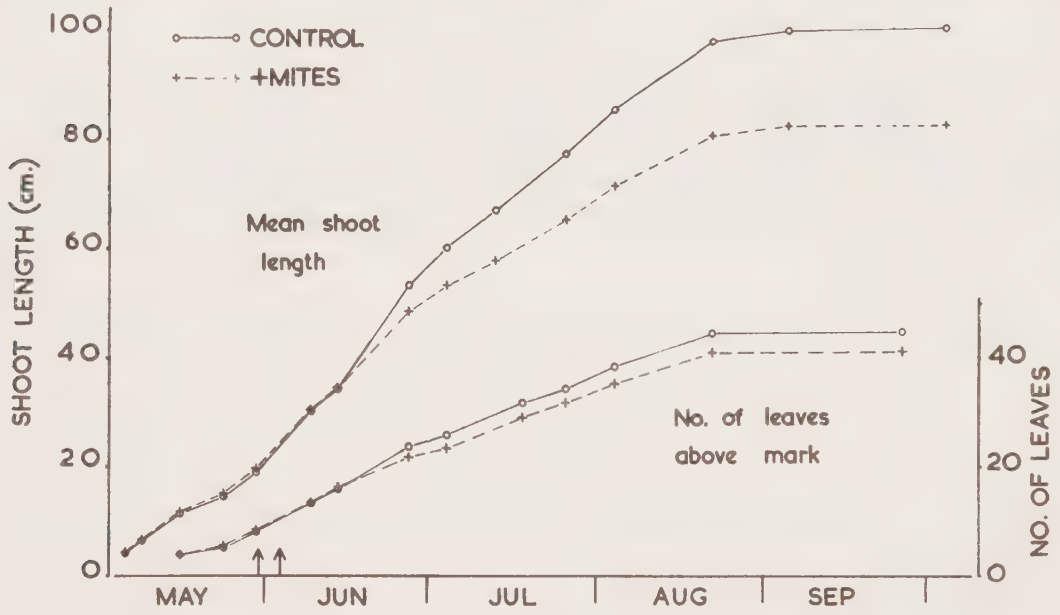

Fig. 1.

Length of shoots and production of leaves on mite-infested and control plants. Dates of inoculation are arrowed

compared. The divergence of the curves for the two groups of plants through the season was again apparent for both upper and lower shoots. The mean length of the upper shoot on the control plants as measured on 22nd August was significantly greater than that of the mite-infested plants ($P<0\cdot01$). The lower shoots did not differ significantly although the mean for the controls was numerically the greater.

The curves of the mean number of leaves above the marked leaf on each shoot (Fig. 1.) suggest that a slight difference in the rate of leaf production occurred after inoculation with mites. However, the numbers of leaves produced by the two groups of plants did not differ significantly. The mean total number of leaves, including scale leaves, produced per shoot during the whole season was 54.5 on the controls and 51·7 on the shoots with mites.

The internodes of the mite-infested shoots produced after inoculation were shorter than the corresponding ones on the control shoots. This is as expected since although the plants with mites had shorter shoots they produced a similar number of leaves.

A few measurements were made of the areas of leaves produced in the latter half of the season ; these indicated that the leaves on the mite-infested plants were slightly smaller.

Over the whole season the mean relative growth rate (excluding leaves) of the mite-infested plants was only 84% of that of the controls, this difference being significant ($P<0\cdot001$). The total dry weight (excluding leaves) of the plants with mites at the end of the season was only 71% of the controls.

The estimated gain in dry matter of the different parts of the plants is shown in Fig. 2. The mites not only reduced the growth of the inoculated plants but modified the distribution of the increase in dry matter. Thus, although the weights of the *leaves* did not differ significantly, the increase in dry weight of the *roots* of the mite-infested plants was only 44% of that of the control plants ($P<0\cdot001$).

The remarkable effect of the mites on the relationship between the two shoots on each plant was again evident. Although the weights of the upper shoots differed ($P<0\cdot01$), the difference between the lower shoots was just below significance. The gains in dry matter of the old stems of the two

treatments also differed significantly ($P<0{\cdot}01$). The increase in weight of the whole plants (excluding leaves) infested with mites was only 65% of that of the controls.

Measurements of shoot and stem diameters showed that the mites caused a reduction in the rate of thickening of the shoots and of the old stems. The reduction in the final length of the shoots was even greater ; this resulted in the shoots of the two sets of plants differing slightly in shape. The gain in dry weight of the plant parts (Fig. 2) provided further evidence that mite infestation did not reduce

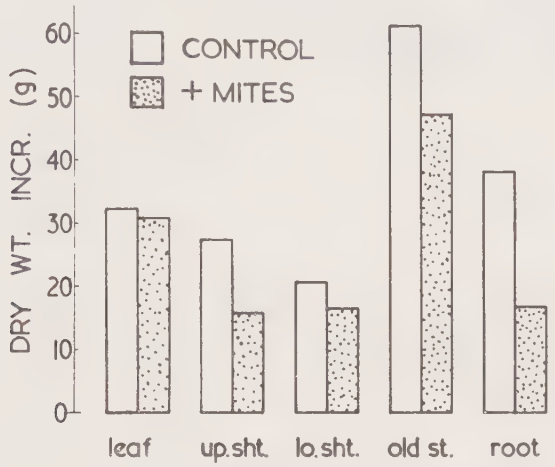

Fig. 2.
Increase in dry matter of the plant parts over the whole season.
up. sht.—upper shoot ; lo. sht.—lower shoot ; old st.—old stem

thickening as much as it did extension growth. The increase in weight of the old stems (thickening only) of the plants with mites was 77% of that of the controls, whereas the mean weight of all the new shoots with mites was only 67% of the controls.

Discussion

No counts of the mite populations were attempted after inoculation, but records of the condition of the plants were made and the following observations indicate the development of visible mite damage.

By 3rd June, four days after the first mites were put on the plants, the lowest leaves showed the speckled appearance characteristic of the earlier stages of mite damage ; the majority of the leaves, however, showed no signs of damage, although some of the mites had moved to the upper leaves. On 13th July distribution appeared to be fairly uniform throughout the shoots. At this stage the advent of predators may have checked the build-up of damage before they were eradicated with DDT. By 4th August the lowest leaves were a silvery, greyish-green colour, and considerable damage was visible on nearly all leaves. The overall foliage colour was a much duller and browner green than that of the controls on 17th August and a marked bronzing of many of the leaves had developed. These bronzed leaves were very brittle ; many of them abscissed before 26th September, whereas few fell from the control plants. The mites began to lay winter eggs on the stems about 22nd August.

Van de Vrie (5) also recorded early leaf-fall from trees with bronzed leaves. The reduction in shoot growth caused by the mites in the experiment described above substantiates Van de Vrie's observations on their effect on the length of the current year's shoots of 15-year-old apple trees.

The data shown in Fig. 1 indicate that the effect of the mites on the growth of the inoculated plants became evident from about the middle of June, when the curves first begin to diverge. This was 2-3 weeks after the inoculations and at a time when little damage to the leaves was apparent, only the lowest ones showing much speckling, although some of the mites had spread to higher leaves.

The exact nature of the damage caused by the fruit tree red spider mite feeding on leaves is not known. It appears to be generally accepted that the mite feeds mainly from the lower surface of the leaf, forcing its stylets through the lower epidermis and spongy mesophyll before penetrating a cell of the palisade mesophyll from which it removes part or all of the contents (1,2,3,5). Although Boulanger (3) found that mites reduced the chlorophyll concentration in leaves of Red Delicious apple by up to 40%, he concluded that ' a reduction in the chlorophyll content of injured leaves may take place before

photosynthesis and transpiration of these leaves are affected '. Moreover, evidence from other physiological investigations suggests that under natural conditions the chlorophyll content is never likely to be the factor limiting photosynthetic processes in normal leaves. It therefore appears unlikely that the damaging effect of feeding mites observed at such an early stage in the experiment described was primarily due to the removal of chlorophyll.

Boulanger's (3) investigations also revealed that the rate of net carbon dioxide assimilation by mite-damaged leaves was lower than that of control leaves, and that transpiration was also affected. It is, however, apparent that the effects of mite damage on growth are not yet fully explained and that the processes involved in the actual feeding by a mite are not yet adequately understood ; a further knowledge of these is desirable before the full effects of mite injury on fruit plants can be finally assessed.

Acknowledgements

The author wishes to thank Dr. G. H. L. Dicker and other members of the Entomology Section for their help ; also Mr. P. Sprent and others of the Statistics Section for the statistical analyses.

Summary

The growth of young plants of Brompton plum inoculated with fruit tree red spider mites was compared with that of healthy control plants. The mites caused a large reduction in the rate of shoot growth, and the relative growth ot all parts of the plants was also affected. The increase in the roots of the mite-infested plants was only 44% of the controls. Measurements of shoot length at frequent intervals indicated a damaging effect of the mites at a very early stage following inoculation.

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EXTREME PRUNING TREATMENTS ON APPLE STADDLES

By D. H. MAGGS

The aim of growth studies on fruit trees is to enable the fruit grower to grow orchard trees to his requirements. At first sight this might seem merely to mean keeping tree size manageable and increasing the duration of profitable cropping. Desirable though these two objectives are, they are not the limits to which we hope to push tree performance, nor should we allow optimum tree form to be determined solely by considerations of spraying equipment and crop-handling ; it must be found whether there is an optimum physiological tree form, and if there is, this must become the basis of management efficiency. This form will be defined basically as the one which gives the optimum yield of fruit from the available light energy; and in effect the aim of the physiology programme is to turn this from a convenient and tranquillizing form of words into practical recommendations.

Given the photosynthetic production of the foliage, what are the conditions under which this is greatest, how can the greatest part of it be turned into fruit and the necessary least into tree structure, and by what means can the consequences of seasonal variations be minimized ? We have previously described the experimental approach to these problems (6). One requirement of them all is the estimation of the *total* increment of the tree as well as that of a specified fraction—usually crop. In these experiments it is not enough to be able to say that any particular treatments will give greater yields than certain others. The efficiency of the process must also be known—from such an amount of foliage, so much increment has been produced, of which such a fraction is crop. This requirement to know the total increment has led in the first place to the use of small weighable experimental trees, and also to a keen interest in the work of the Statistics Section on assessing total weight from other correlated characters such as girth. At the same time, it is realized that generalizations derived from small trees will be of two kinds—those resulting from the small size of the tree, its limited soil volume and the consequences of its previous history, and those resulting from its woody anatomy and the inevitable enlargement of its ' body '. It is only this second class of result which will also be applicable to larger, mature trees, and so must be experimentally separated from the first. To do this requires additional tests on larger trees ; such tests have not been completed, but a small experiment, on eight trees about 10 times as big as those previously used, has reached a stage at which some separation of the two classes of result can be made.

These trees were 6-year staddles of the rootstock variety Crab C pruned in varying degrees of severity. The treatments went well beyond the range of normal pruning, being designed to test the plant's reactions at the extremes of pruning. Such extreme treatments are a necessary part of any programme aimed at pushing tree performance to its physiological limits, as only they can reveal which component of the growth complex is liable to break down. For this reason physiological experiments sometimes have an air of deliberate impracticability, although it is through such extreme experiments, in horticulture as in other industries, that technological advances will come.

In the winter the trees were carefully lifted, weighed and replanted ; the first tree was left intact, the second had the 1-year wood and spurs pruned off, the third the 2-year wood, the fourth was headed to the top of the main stem, and the others were cut back increasingly down the main stem, so that the eighth was a 2-in. stub above the roots. The trees were uniform, and some idea of the pruning can be obtained from Line *b* of Table I which gives the length of stem from ground level to the tip of the branch after pruning. This pruning was done in March 1958 ; the following October, when most of the foliage was still on the plants, the trees were lifted and weighed, and after pruning off all the

TABLE I

GROWTH OF PRUNED STADDLES (3-YEAR AVERAGES)

(*a*) Tree No.	1	2	3	4	5	6	7	8
(*b*) Length after pruning (cm)	214	225	171	148	123	75	25	3
(*c*) Degree of pruning	1·00	1·01	1·23	1·48	1·79	2·67	8·00	14·00
(*d*) Percent leaf in increment	18	21	21	24	21	28	28	30
(*e*) Percent stem in increment (New and old stem thickening)	57	56	58	59	59	50	58	55
(*f*) Pruning response	·02	·10	·43	·76	1·31	1·30	2·42	1·40

new shoots, spurs and new roots, they were replanted in their original sites. The same procedure was repeated for the following two years. Since the heavily pruned trees produced more extension growth than those lightly pruned, they were in effect more heavily pruned each year. After three years the trees were replanted in a different arrangement to see how far the increment was dependent on the site. This note covers the first three years. For each year's growth, the weight of foliage, new shoot, new roots and increase in weight of the original 'body' were known for each tree, so that a direct check could be made against the results expected from previous experiments for young trees. These comparisons are summarized and discussed briefly.

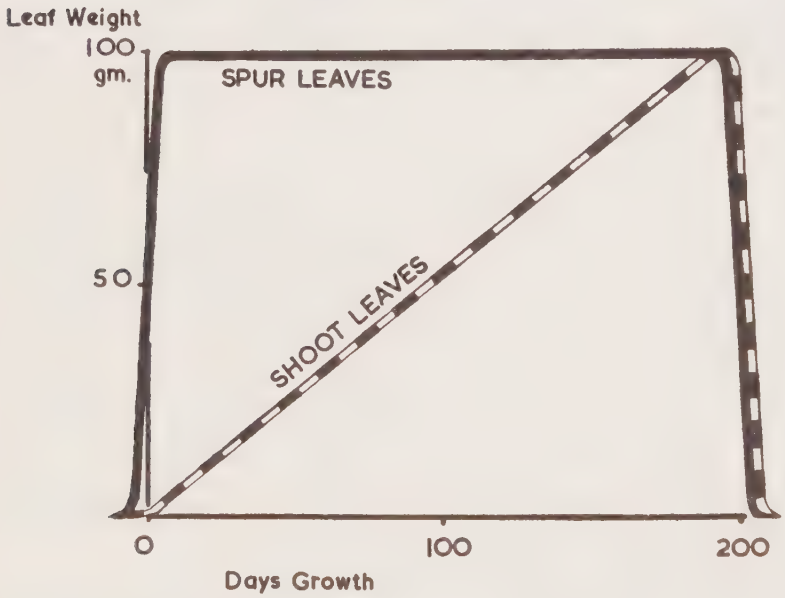
1. Distribution of increment

Expected for young trees

The fraction of the total increment utilized as leaves or as new root or as stem is constant, irrespective of the increment (4, 7).

Found for 6–9 year trees

Total stem fraction of the increment was constant, but the leaf fraction tended to increase with increasing severity of pruning (Table I, lines *d* and *e*) and the root fraction correspondingly decreased.



Exposure of spur leaves = 100 g leaf for 200 days = 20,000 g days.

If productivity of shoot and spur leaves is ·05 g increment per g leaf per day, then

Production by 100 g leaves = ·05 × 20,000 = 1,000 g and fraction of leaf in increment = 100/1,000 = 10%.

Exposure of shoot leaves = ½ × 100 g leaf for 200 days = 10,000 g days, and

Production by 100 g leaves = ·05 × 10,000 = 500 g, and fraction of leaf in increment = 100/500 = 20%

FIG. 1

Productivity of equal weights of shoot and spur leaves assuming they have the same efficiency per g leaf per day (0·05), and that the amount of shoot leaf increases steadily from beginning to end of the season

Comment.—The differences may be partly accounted for in terms of the varying proportions of shoot leaves and spur leaves (1). The originally unpruned tree developed few extension shoots, almost all the foliage consisting of spur leaves (1,178 out of 1,266 leaves in the third year), while at the other extreme those pruned well down the main stem (trees 6, 7, 8) bore 0·12 spur leaves to 100·500 shoot leaves. Although the spur leaves were fully developed for photosynthesis soon after the beginning of the growing season, only a few shoot leaves were developed by that time. Consequently, the production from 100 g spur leaves over the whole season should be twice that from the same quantity of shoot leaves (Fig. 1), provided that both kinds maintained constant efficiency throughout the season and the production of shoot leaves proceeded steadily from the beginning to the end of the season. It follows that the percentage of leaf in the increment for spur leaves should be half that for shoot leaves. In fact, the spur-foliaged tree carried 18% of its increment as foliage as against 30% or less for the shoot-foliaged trees 6, 7, 8. These trees had only just stopped growing when dug up, so that the evidence favours the suggestion that over the whole season spur leaves are less efficient, as measured by grammes of increment per gramme of leaf per day, than shoot leaves. Nevertheless, it must be

emphasized that the whole-season production by the spur leaves was greater than by the shoot leaves since they formed an early canopy which took advantage of the longest and warmest days of the year. As Watson (10) has pointed out, it is failure to develop such an early cover of foliage under these most advantageous growing conditions that is limiting the production of many field crops in this country.

The corresponding change in percentage root (most root on the lightly pruned trees and least on the heavily pruned) is similar to the inverse relation between leaf and root already reported as a result of shading (5) and again suggests an advantage to the trees producing an early canopy of spur leaves. Certainly the thick fuzz of new root on such trees compared most favourably with the few long, thin roots on the heavily pruned trees.

2. Pruning response

Expected for young trees

Pruning response may be measured by

$$\frac{\text{New Stem}}{\text{Old Stem Increment}}$$

and degree of pruning by

$$\frac{\text{Unpruned Stem Length}}{\text{Stem Length after Pruning}}$$

The pruning response is linearly related to the degree of pruning (4).

Found for 6–9 year trees

So long as the main stem was left intact the pruning response increased with the degree of pruning. With more severe pruning the response only increased slightly (Table 1, lines *c* and *f*).

Comment.—Buds on the heavily pruned trees grew out later in the spring. Possibly this was because the normal axillary buds of the stem had been pruned away in the nursery, and adventitious ones had first to be formed before growth could appear. This in itself seems inadequate to account for the discrepancy, since young trees also gave a straight-line pruning response regardless of a (smaller) lag in bud-break. A series of exploratory experiments on mature trees have likewise given inconsistent results from severe pruning ; it may be that the young-tree type of pruning response only applies to shoots up to about four years old. This would include most of the pruning performed on normal orchard trees.

3. Growth rate

Expected for young trees

Increments are not directly proportional to planting weight (4).

Found for 6–9 year trees

Each year's increment was directly proportional to the weight of the tree at the beginning of that year (Fig. 2).

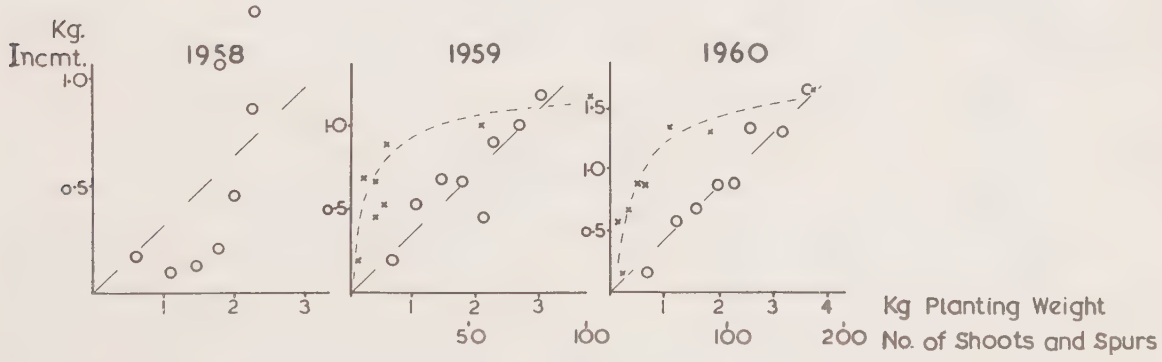


FIG. 2

Relation between increment in fresh weight and planting weight (o) and number of shoots (x). The straight lines join zero planting weight and increment with mean planting weight and increment, and the closer the values (o) lie on this line, the more nearly will the increment be proportional to planting weight

Comment.—The relation between initial weight and subsequent growth depends on a number of factors. The simplest case is where the size of the regions that are actively growing is proportional to the size of the propagule or young plant ; in this case the rate of growth follows the compound interest law, so called by analogy with the increase of money at a fixed interest rate. Examples of this may be found in the growth of different sized seeds of sunflowers and clover (2, 3). With larger organisms it is difficult to measure the separate effect of size on growth since there are many other associated differences number and condition of buds, proportions of the different kinds of cells, maturity, and, possibly, age.

In woody plants, because of the dilution of the growing regions by varying amounts of inert wood, the condition for compound interest growth would only apply directly if the wood did in fact make some contribution to growth which was proportional to its weight (8). What has been found with young trees is that small plants grew relatively faster than others several times their weight, as would be expected from the relatively greater proportion of their growing regions to weight. This relation held when the larger and smaller plants were made to develop the same number of shoots. When they were allowed to develop different numbers of shoots, each shoot behaved as a more or less independent unit, and the increment increased with shoot number. This fact was suggested as contributing to Vyvyan's observation that trees which had originally grown at different rates because of rootstock differences, subsequently grew at the same rate of compound interest (9), that is, they would double their weight in approximately the same time. The present results agree with Vyvyan's observation, but as Fig. 2 shows, they cannot be accounted for on the basis of shoot number alone, and several other factors must operate to produce the approximation to a straight line relation between initial weight and increment found in this experiment.

Summary

Pruning treatments ranging from nil to very severe were applied to 8 six-foot staddles of an apple rootstock. Each year subsequently the trees were lifted, and replanted after pruning off leaves, new stem and new root. The fresh weights of total tree and pruned parts were obtained at the same time.

The percentage of leaf in the increment increased with increasingly severe pruning, while new roots decreased ; the percentage of total stem (new plus old stem thickening) did not change appreciably. The importance of spur leaves, which can take full advantage of summer growing conditions, is emphasized.

The ratio of new stem weight to old stem increase in weight rose with severity of pruning up to the point where approximately half the main stem had been pruned, and tended to remain constant with more severe pruning.

The increase in weight of each tree during the year was proportional to the weight at the beginning of the year. No satisfactory argument could be found to account for this.

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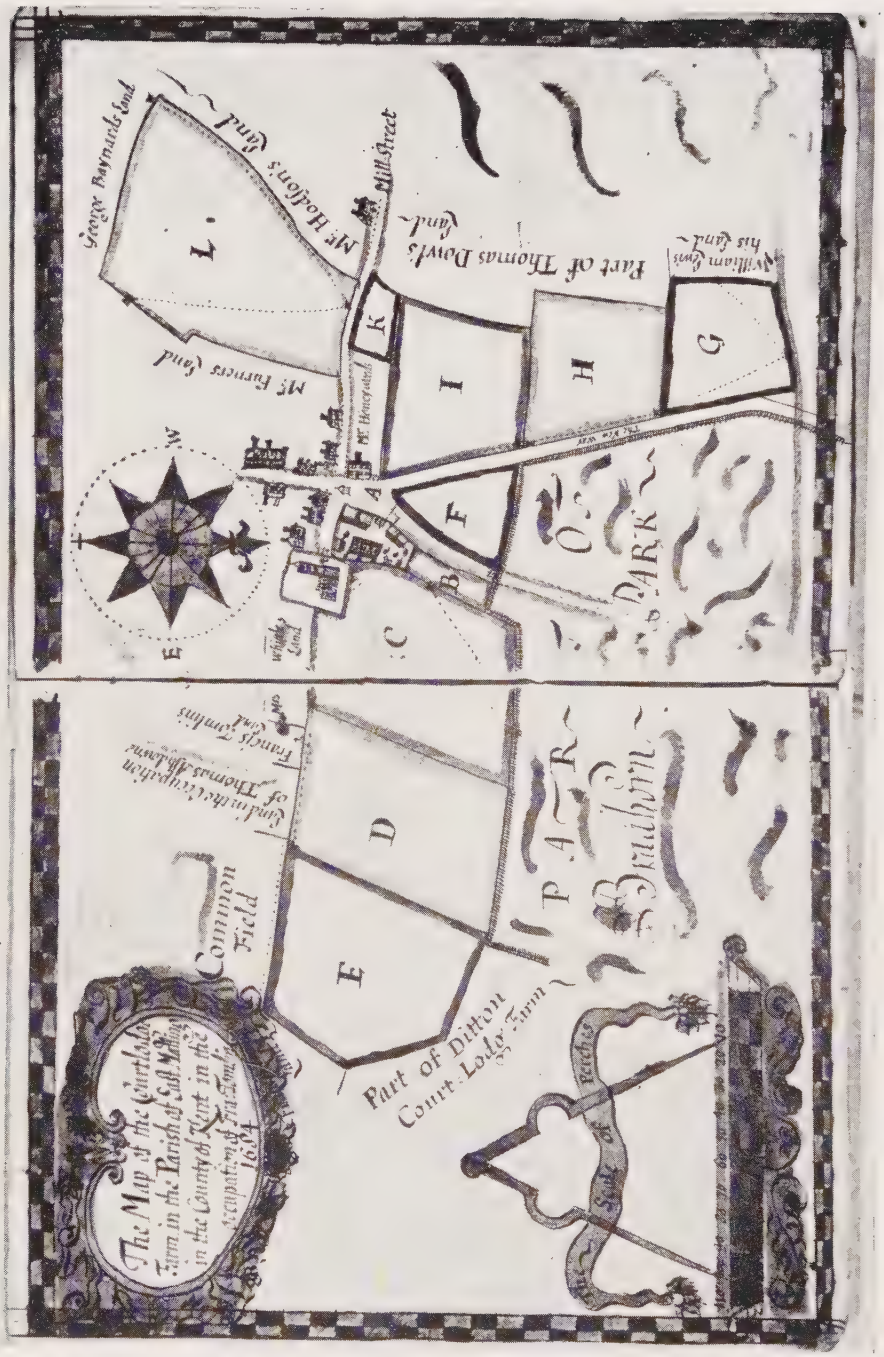

Fig. 1.

Reproduction of map CC of 1684

A—The Yards Gardens & Old Way ; B—The Little Croft ; C—Church Field ; D Farther Churchfield ; E—Bramton
F—Triangle Croft ; G Lower Blacklands ; H Middle Blacklands ; I Upper Blacklands ; K The Playing-place
L—Cottman-Field

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STATISTICS AND RECORDS

SOME FURTHER HISTORICAL INFORMATION ABOUT RESEARCH STATION LAND

By S. C. PEARCE and D. W. P. GREENHAM

Since the publication of two papers (1,2) on the history of Research Station land, further information has been obtained as a result of the discovery of two more old maps. Because this new information both amplifies and corrects these earlier accounts it is presented here.

The first map was found in a book of plans of the Twisden estates recently deposited in the Kent County Archives Office (Map CC). It is dated 1684 and relates to Church Fields, East and West, and the southern part of Bradbourne Park. It is reproduced as Fig. 1. First it shows that the lightly drawn boundaries of Map B of 1706 are intentional despite doubts previously expressed (1). The three main fields into which the area was divided were called *Bramton** (17·6 acres), *Farther Churchfield* (16·6 acres) and *Church Field* (15·4 acres). The use of the name *Bramton* for this area had been the subject of doubts (1) because the name was that of a manor in Ditton parish, but other examples occur of a field next to a boundary being called after the adjoining district. Thus Ditton Fields refers to an area in East Malling, while on the other side of the parish boundary in Ditton the name *Malling Field* occurs in Map DD.

The map also helps to elucidate the changes in roads. In 1684 permission to divert the East Malling-Larkfield road had only recently been granted (Manuscript II of 1676), and Map CC shows both *The New-Way* and the old. This latter is evidently the easterly of the two roads shown in Map B of 1706, not the westerly as was previously supposed (1). The map shows also a small field to the east of the *Old Way*, 1·2 acres in extent, called *The Little Croft* and another of 3·7 acres to the west called *Triangle Croft* ; these, together with the 3·0 acres occupied by *The Yards Gardens & Old Way* and the three fields already noted, correspond exactly in total acreage (57·5) with the area called *The Church Fields* in 1706 (Map B). Hence the boundaries in 1684 were probably those of 1706.

No mention is made in Map CC of watercourses, which is unfortunate in view of their confused history about this time. The map (Fig. 1) does, however, show some paths, which do not correspond exactly with those shown in Map B. Further it shows the positions of Court Lodge and adjacent erections before the rebuilding in about 1700.

The area covered by this map appears to form part of the land purchased from the church by Sir Thomas Twisden I in 1664, and is shown by the title of the map to have been in the occupation of Francis Tomlin in 1684. In 1706 (Map B) it was farmed by the Twisdens, who had meanwhile rebuilt Court Lodge. This renting of the land by the Tomlin family perhaps explains why the manorial court of the period met ' *coram Thoma Tomlyn* ' (Manuscript III). One would, of course, expect it to meet at a house called ' Court Lodge ', but the nearest building known to have been associated with the Tomlins was by the present Grange, and this had caused confusion.

Although the new information all relates to conditions of long ago, it may well have a bearing on present use of the land for experiments. Thus, the south-west corner of Bradbourne Park once had more buildings and roads than was previously realized. In particular, the *Old Way* is now known to have crossed Plot P11. This once formed part of a route from Teston to New Hythe, and the discovery of Roman remains at several points near it testifies to its possible age and importance.

The other map (DD) is one of Ditton Court Farm in 1772, and is of interest in several respects. In general, field boundaries west of Kiln Barn Road are much as in Map E of 1789 (2), but names are given as well. The field south of the *Maidstone Footway* is called Kiln Field as at present. There were four fields to the north of the footway, some bearing designations so artificial that the areas may not have been long established. Of these four fields, that to the north-west was called *Upper Ditton Rough* and that to the north-east *The 12 Acres* ; the fields to the south of them were referred to respectively as *The 12 Acres above Upper Ditton Rough* and *The 8 Acres above the 12 Acres*. A footpath is shown crossing the last-named diagonally between the south-west and north-east corners. A longer footpath, from Ditton village, runs parallel to and somewhat to the east of the parish boundary between East

* The practice will be continued of giving in italics names no longer in use and those that have changed their meaning.

Malling and Ditton. The course of the *Maidstone Footway* across the area is the same as in 1789 (Map E).

Of particular interest is the identification of the feature marked on Map E at the south end of Plot K7 ; this was a lime kiln, after which it is now supposed that the field was named. This no doubt accounts for the severe lime-induced chlorosis recently shown in this part of the field by apple trees.

The overlap between the area formerly considered (2) and that shown on this map extends east of Kiln Barn Road only as far as the western boundaries of *Deadman Hop Ground* and *Lower Knoxes*, as shown on Map V1 of 1842 (2). In this area boundaries and names are much the same as those in Map V1. Thus, *Coalpit Wood* is called *Coal-Pitts* ; *Newgate* and *Newgate Wood* are together termed *Newgate Field, Shave included*, the *Shave* not extending quite so far to the north as did the wood of 1842; and *Palmer's Rough* is spelled *Palmar's Rough*.

Summary

Information obtained from maps of the East Malling Court Lodge Farm (1684) and Ditton Court Farm (1772) is considered in relation to the previously published history of the land used by East Malling Research Station.

Acknowledgements

The help of the following is gratefully acknowledged : Dr. F. Hull of the Kent County Archives Office, Mr. L. R. A. Grove of Maidstone Museum, and Mr. M. Thompson-Coon, lately of Ditton Court Farm.

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The manuscripts and maps have been numbered and lettered so that those referred to in the previous papers (1,2) may keep their original designation, and so that no letters are used twice.

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A COMPARISON OF THE GROWTH AND CROPPING OF APPLE TREES OF DIFFERENT HABIT

By C. S. MOORE

It is a common experience that apple trees that are similar in size at planting often grow at different rates although they are on clonal rootstocks, and this results in considerable variation in tree size after only a few years' growth. Sometimes much of this variation is positional, but often neighbouring trees differ greatly in size and habit so that there is a considerable random element in the variation. It is generally believed that tree habit and size are associated and that growth in the first year or two after planting often determines future development. The purposes of this study are to find out precisely what differences are associated with habit and to trace how and when they arise.

Material and method

Trees in three trials were studied, comprising the following stock/scion combinations : Cox's Orange Pippin on M.VII, Lane's Prince Albert on M.VII and Laxton's Superb on M.II. The first two trials were planted in winter 1950-51 and the third in winter 1945-46.

The trees were classified visually into three categories, viz. : ' erect ', ' intermediate ' and ' spreading ', by two independent observers. The Cox's Orange Pippin trial was recorded in June 1959 and the other trials in June 1961. The main criterion adopted was the angle of each of the main branches with the vertical, but in doubtful cases account was also taken of the extent to which the distal portions of the branch tended to bend downwards. A main branch was considered to comprise at least 10% of the total branch volume of the tree, the smaller branches and young shoots being ignored.

It should be emphasized that ' spreading ' and ' erect ' here refer primarily to branch angles, not shape of tree head as measured by the height:spread ratio. Because they were larger, many of the ' erect ' trees had greater actual spreads than those classified as ' spreading '.

No arbitrary rules can be applied to classify the habit of apple trees, and slightly different standards are needed when judging trees of different varieties. Only those trees considered erect or spreading by both recorders were included in these classes ; trees over which there was disagreement, together with those considered intermediate, were discarded.

In order to minimize positional variation, trees were paired with the nearest tree of the opposite habit, excluding odd trees which could not be paired. With the Cox's Orange Pippin and Lane's Prince Albert trees there were no restrictions on the pairing due to treatments, but the Laxton's Superb trees were in a trial of sward treatments, and pairs of comparable trees could be obtained only within the two-tree plots. Where differences of habit were more marked, as with Cox's Orange Pippin, a larger number of pairs was obtained—27 pairs from the 96 trees of this variety compared with only 7 pairs from 192 trees of Lane's Prince Albert, where most were spreading. The Laxton's Superb gave 8 pairs from 60 trees but would have produced more if no restrictions on pairing had been imposed by treatments.

Results

From Table I it can be seen that by 1960 the girths of the erect trees of all three varieties were larger than those of the spreading trees, but as the history of the trees is traced back the differences decrease and were non-existent when the trees were planted. The later crops of the erect trees were also larger, but the first crops were heavier on the trees now classified as spreading. Thus the Lane's Prince Albert trees in this category had the heaviest crop in the first year of cropping and the Cox's Orange Pippin in the first four years. The Laxton's Superb had the heaviest crops in the first, third and fifth years ; these were ' off ' years for this variety indicating that spreading trees were more regular bearing. Spreading trees also cropped more evenly than the now erect trees during the first few years.

In Fig. 1 the accumulated mean crop has been plotted against the mean girth for both spreading and erect trees for all three varieties. The spreading trees have consistently produced a greater crop for their size as measured by trunk girth.

Other records available for Cox's Orange Pippin only, show that the erect trees have consistently made more wood growth and have been pruned more heavily (Table I). The number of fruits produced

TABLE I

PERCENTAGE ADVANTAGE OR DISADVANTAGE OF 'ERECT' TREES ABOVE 'SPREADING' TREES FROM YEAR OF PLANTING TO 1960

Year	Lane's Prince Albert		Laxton's Superb		Cox's Orange Pippin						
	Girth	Crop	Girth	Crop	Girth	Crop	Wood-growth (length)	Prunings	No. of fruit buds	No. of fruits	No. of fruits / No. of fruit buds
1945	—	—	−2	—	—	—	—	—	—	—	—
1946	—	—	8	—	—	—	—	—	—	—	—
1947	—	—	13*	−91	—	—	—	—	—	—	—
1948	—	—	13**	153*	—	—	—	—	—	—	—
1949	—	—	39**	−57**	—	—	—	—	—	—	—
1950	−2	—	40**	113**	0	—	11	—	—	—	—
1951	−2	—	44**	−70	2	—	8	6	3	—	—
1952	−2	—	46***	80**	4	—	20**	60***	—	—	—
1953	3	−40	48***	4	7*	−35	23**	51	−23*	−41**	−20
1954	6	13	48***	96*	9***	−26*	38***	51***	11	−30**	−41***
1955	18	85	46***	96	11***	36***	50***	65***	6	−39***	−45***
1956	24*	112	47***	75	11***	−27**	57***	41***	5	−26*	−32**
1957	28*	−10	44***	89*	14***	2	43**	32	23*	3	−17*
1958	35**	69	44***	101	14***	18**	32**	36**	12	23**	−6
1959	37**	92	44***	170	14***	1	32**	9	16	−10	−34
1960	38**	65	44***	77	12***	15*	—	—	—	—	—

* Significant at 5% level. ** Significant at 1% level *** Significant at 0·1% level.

each year follows a pattern similar to that of crop weight. With the exception of 1953 the erect trees regularly produced more fruit buds, but the spreading trees have always produced the highest ratios of fruits to fruit buds.

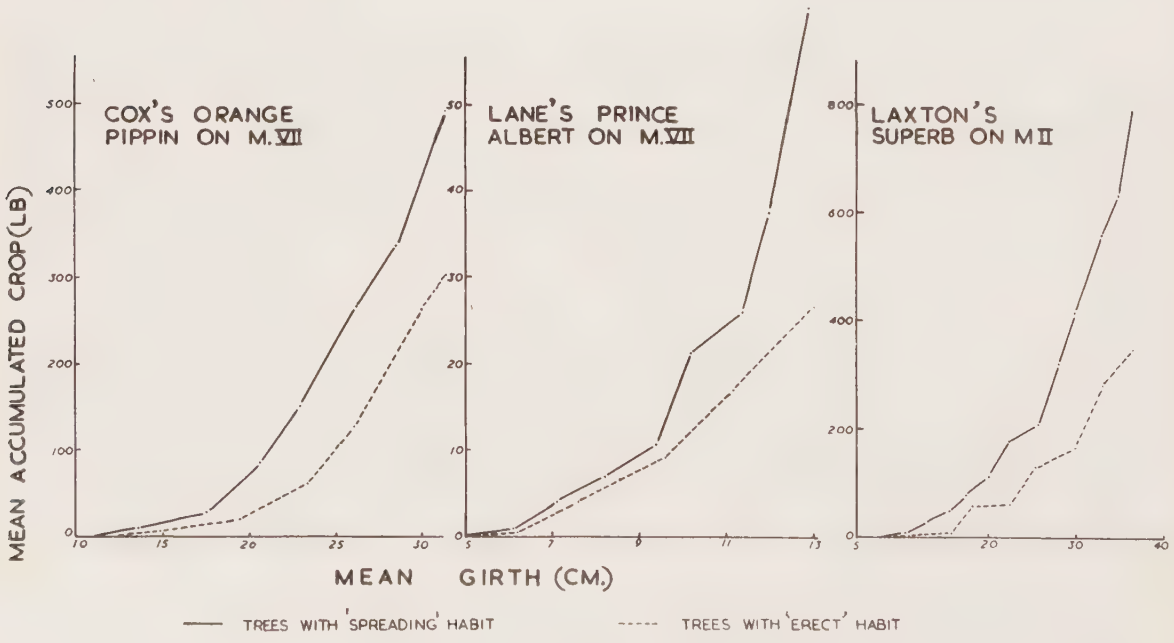
COX'S ORANGE PIPPIN ON M.VII
LANE'S PRINCE ALBERT ON M.VII
LAXTON'S SUPERB ON M II
MEAN ACCUMULATED CROP (LB)
MEAN GIRTH (CM.)
TREES WITH 'SPREADING' HABIT
TREES WITH 'ERECT' HABIT

FIG. 1.

Crop relative to trunk girth. The curves for the erect trees have not been extended beyond the values of the last available mean girths for the spreading trees

Detailed early records for Cox's Orange Pippin

Detailed early records of the nursery trees and the first year's growth in the orchard are available for Cox's Orange Pippin. Comparing erect and spreading trees, from records taken at planting, there is no reason to suspect that the small differences in tree weight, stem girth or stock length were anything but chance effects. Maiden height was the only record for which differences were significant at the 5% level, the erect trees being taller ; this is of interest because these trees also tended to be less feathered than future spreading trees. Thus the trees that were later to become spreading were more spreading in the nursery also, having made a certain amount of lateral growth at the expense of growth in height. Attempts were made to combine these data into a single series of numbers, such as the ratio of the length of feathers to maiden height or their weighted sum*, that would demonstrate a clear difference in the nursery between the two types of tree ; however, the differences, though marked, were not significant even at the 5% level.

In June 1951 all trees were pruned to three branches. The prunings were divided into length of main stem cut off and one year wood removed ; slightly more 1- and 2-year-old wood was removed from the trees which were later to become spreading. From the end of the 1951 season onwards, the position was reversed and more was removed from the erect trees.

In autumn 1951 the angles from the vertical of the branches formed in the previous summer were measured. The aggregate branch angles of trees that were judged to be erect in 1959 were 4·3% smaller than those of spreading trees, i.e. the erect trees were slightly more erect in 1951. But when the angles of the highest branch on each tree were compared, those of the erect trees were 9·8% smaller than those of the spreading trees. Thus the highest branch of a 2-year-old tree appears to be the most important in assessing future tree habit. This is in line with the work of Wareing and Nasr (4) on the apple rootstock M.III. These workers concluded that bending exerted its most pronounced effect on the highest branch, and Lalatta (1) working with palmette-trained trees found that the beneficial effects of bending on fruit set were most marked on the upper branches. For these reasons the highest of the first formed branches have been especially considered, and indeed, they appear to be the most important in determining future habit.

Two criteria are suggested that might enable selection to be made of future erect trees : (*a*) the highest branch should be more erect than any other, and (*b*) one or more branches should be within 35° of the vertical. The numbers of spreading and erect trees as classified on these criteria are given in Table II.

TABLE II

Branch angles 1951	Habit in 1959			Percentage of erect trees
	Erect	Spreading	Total	
Highest branch not the most erect and no branches within 35° of vertical	11	18	29	38
Highest branch the most erect but not within 35° of vertical	7	7	14	50
One or more branches within 35° of vertical but highest not the most erect	3	2	5	60
Highest branch the most erect and within 35° of vertical	6	0	6	100

The difference between 38% and 100% in the last column is significant at the 5% level. From this it is evident that trees which in their first year had a branch at a small angle from the vertical (particularly the highest branch) subsequently showed a tendency to produce erect growth.

Discussion

The time that differences in tree shape appear in the orchard as well as the effect of these differences on cropping have been investigated, but no attempt has been made to ascertain the causes. Early cropping is associated with less vigorous growth, and trees that put a greater proportion of their energy into early cropping grow less rapidly. Spreading trees produce more fruits per fruit bud and have heavier crops in relation to their size but their actual crops soon fall behind those of the erect trees. These differences in growth and cropping thus appear early and become more pronounced as the trees develop.

For experimental work it is obviously desirable to grow plantations that are as uniform in habit as

* Appropriate weights were obtained from a component analysis of maiden height, length of feathers and initial girth.

possible. There is some evidence that nursery trees of Cox's Orange Pippin are not all equally predisposed to either erect or spreading habit. The balance between feathering and leader growth established in the nursery may continue into the orchard, but since some varieties do not feather there must be other factors involved.

Deblossoming for several years may ensure that trees develop an upright habit ; thus Preston (2) found that deblossoming lightly pruned trees for the first six years resulted in larger trees with a more erect habit than those allowed to crop normally. In the seventh year the crop of the deblossomed trees almost equalled the cumulative crop of the normally treated trees, whilst the later crops were higher on the deblossomed trees (3). Deblossoming for the first few years appears, therefore, to be a method of minimizing variation in the relative amounts of energy directed to growth and fruiting, without reducing the cumulative crop over a number of years.

Although erect trees soon bear heavier crops, they bear smaller crops per unit of girth (Fig. 1). Thus the relationship between trunk girth and crop appears to be complicated, a point which should be taken into consideration when crop is being calibrated by trunk girth measurement.

Summary

On a branch angle basis trees were divided into ' spreading ' and ' erect ' groups, and comparisons made between the girths and crops since planting. There was no initial difference in tree size between erect and spreading trees but the earlier crops were heavier on the spreading trees. Erect trees eventually grew larger and produced heavier crops, but the crop per unit of trunk girth was heavier on the spreading trees. From early detailed records there was a suggestion that heavily feathered trees are predisposed towards a spreading habit. The angles at which the early branches, particularly the highest, are formed provide an indication of future habit.

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FRUIT NUTRITION

THE EFFECT OF MAGNESIUM NUTRITION ON THE INCIDENCE OF POWDERY MILDEW ON POTTED APPLE ROOTSTOCKS

By ELSIE M. FORD and E. L. FRICK

Experiments have been described (Ford and Frick, 1961) in which some control of apple mildew (*Podosphaera leucotricha* (Ell. and Ev.) Salm.) was achieved by foliar sprays of Epsom salt plus a wetting agent. This partial control was attributed to the deposit of Epsom salt remaining on the leaf surface.

The possible influence of magnesium nutrition on the incidence of mildew was also investigated, but the results were inconclusive. In 1959 low magnesium nutrition apparently increased the incidence of mildew whereas in 1960 there was little difference in mildew susceptibility between plants grown with an adequate supply and those grown without magnesium in the nutrient solution. It was considered that this discrepancy might be due to a difference in the degree of magnesium deficiency. An experiment involving three levels of magnesium nutrition was therefore carried out in 1961 in an attempt to clarify the position.

Material and method

One-year-old layers of MM.102 rootstock were selected for uniformity during autumn 1960; plants for Treatment 1 (Table I) were taken from the stoolbed nursery plots receiving Epsom salt both as soil dressings and as foliar sprays (Ford, 1958), and plants for Treatments 2 and 3 from untreated plots known to be deficient in magnesium.

Plants were stored at 37° F until spring 1961, then potted in sand and each shoot cut back to 3 or 4 buds; they were watered daily with a balanced nutrient solution, using three levels of magnesium (Table I). Previous experience indicated that 48 and 10 p.p.m. magnesium gave adequate and low levels respectively, as judged by foliar symptoms.

In mid-July, 18 plants were selected for mildew inoculation from the 30 plants used for each treatment. Samples of leaves for determination of magnesium content were taken at the time of mildew inoculation and after the lesions had been recorded. Other cultural and experimental details were similar to those of the 1960 experiment (Ford and Frick, 1961).

Results

Growth was good and uniform within treatments, and at the time of mildew inoculation the plants were still growing well. Shoot lengths of plants receiving no magnesium were less than those of plants with low magnesium, which in turn were slightly shorter than plants having adequate magnesium (Table I). There was, however, no difference between the three treatments in leaf size.

No foliar symptoms of magnesium deficiency were apparent on plants receiving adequate magnesium. The older leaves of plants growing with a low magnesium supply became chlorotic around the margins and between the veins; slight interveinal scorching subsequently developed. Similar foliar symptoms were exhibited by plants receiving no magnesium, but the symptoms appeared earlier and were much more severe: leaves on almost half of the lower part of each shoot became scorched and some were shed. The younger leaves, including those used for recording mildew attack, showed marked differences in colour between treatments, varying from a very pale green in the plants receiving no magnesium to a normal colour in those receiving adequate magnesium.

Leaf magnesium content.—The concentration of magnesium (Table I) in the leaves of plants grown with a complete nutrient solution and sampled after the mildew lesion count, was normal (0·22% of the dry weight), whereas that of plants grown with no added magnesium was extremely low (0·06%); a concentration mid-way between these two values was recorded for the mildly deficient plants (0·14%). The leaf magnesium concentrations of similar plants, except those receiving no magnesium, sampled at the time of mildew inoculation were significantly ($P<0·001$) lower: 0·18% for plants receiving a complete nutrient solution and 0·11% for those receiving a marginal deficiency level of magnesium.

TABLE I

MEAN SHOOT LENGTH, MAGNESIUM CONTENT OF LEAVES AND MEAN NUMBER OF MILDEW LESIONS PER LEAF

Treatment	p.p.m. Mg as Epsom salt in nutrient solution	Shoot length (cm)	Mg content of leaves (% dry wt)		Lesions per leaf
			At mildew inoculation*	At lesion count	
1. Adequate Mg	48	34·3	0·18	0·22	10·9
2. Low Mg	10	31·5	0·11	0·14	8·6
3. No Mg	—	22·9	0·06	0·06	7·3
		(P<0·05)	(P<0·001)	(P<0·001)	(P<0·001)

* Mean of 6 plants per treatment. All other figures represent the mean of 18 plants.

Mildew lesions.—More mildew lesions (Table I) occurred on leaves of plants grown with adequate magnesium (10·9 lesions per leaf) than on those of the mildly deficient plants (8·6 lesions per leaf). The lowest incidence of mildew was found on the plants receiving no magnesium (7·3 lesions per leaf).

Discussion

As the magnesium status of the plants increased, so did the incidence of mildew ; the normal plants had 50% more lesions per leaf than the severely deficient ones, the leaves being similar in size throughout all treatments. This positive correlation between the leaf concentration of magnesium and the incidence of mildew in 1961 contrasts with the results obtained in 1960 (Ford and Frick, 1961) when there was no clear relationship, and in 1959 when an apparent inverse relationship existed. It appears, therefore, that the magnesium status of plants does not consistently affect susceptibility to mildew.

In 1959 the plants were grown in soil in pots under unfavourable conditions, with the result that growth was poor and not comparable with that of the two succeeding years. In both 1960 and 1961 plants were potted in sand and watered with nutrient solutions so that the cultural methods in both years were identical, and the only obvious difference between the two seasons was in the weather. In 1961, the plants receiving no magnesium developed pale apical leaves and showed relatively poor growth ; no such effects were, however, observed in 1960 when both the mean maximum temperature and number of hours of sunshine during the experimental period were much lower. Mildew susceptibility was increased by magnesium applications in 1961 only, when shoot length was increased, and not in 1960 when the various treatments did not affect growth. These results would tend to support the observations of Raines (1922) and Smith and Blair (1950) that increased vigour of the host is correlated with increased susceptibility to such diseases as mildew ; on the other hand Yarwood (1949) found an *inverse* relation between growth of beans and susceptibility to powdery mildew, while Trelease and Trelease (1922) found no systematic relationship.

These results suggest that mildew susceptibility is not directly related to the magnesium status of plants but rather to their vigour and leaf condition.

This conclusion in no way invalidates the previous finding that Epsom salt foliar sprays have a direct fungicidal effect (Ford and Frick, 1961).

Summary

One-year-old layers of MM.102 rootstock were used to investigate the possible influence of magnesium nutrition on the incidence of apple mildew (*Podosphaera leucotricha* (Ell. and Ev.) Salm.) following artificial inoculation.

Plants were grown in pots with three levels of magnesium supplied to the roots ; namely very low, low and adequate.

As the magnesium status of the plants increased, the incidence of mildew increased slightly. This result contrasts with those obtained in the two former years and possible causes for this discrepancy are discussed.

It is concluded that mildew susceptibility is not directly related to the magnesium status of the plant. This in no way conflicts with the previous finding that Epsom salt foliar sprays have a direct fungicidal effect.

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PLANT PATHOLOGY

HEAT INACTIVATION OF SOME APPLE AND PEAR VIRUSES

By A. F. POSNETTE, R. CROPLEY and L. D. WOLFSWINKEL

Several viruses that infect apple and pear trees are so prevalent that no healthy plants of some important varieties have been found. Rubbery wood virus (7) is common in many apple varieties and rootstocks (1, 2, 4) ; vein yellows and bark necrosis viruses (3, 5) are widespread in pears, and many varieties seem to be totally infected ; quince stunt virus (3) was present in all 40 plants of Quince C rootstock collected from different localities in England. Methods that inactivate these viruses are described.

Apple rubbery wood

Shoots from a tree of Lord Lambourne infected with a moderately virulent strain of rubbery wood virus were grafted during February 1956 onto potted M.IV rootstocks. In July, when the infected scions had grown to a length of about 35 cm, eight plants were placed in a glass incubator maintained at $37 \pm 2^{\circ}$ C. After 3 weeks' treatment the plants were removed from the incubator and buds from the rubbery Lord Lambourne shoots were grafted onto M.II rootstocks in the nursery, buds from two unheated plants being similarly grafted as controls. After two years' growth the resulting Lord Lambourne trees were examined for rubbery wood symptoms.

All 26 buds from the unheated control plants grew into rubbery trees. Of 51 buds from the heat-treated plants 24 failed to unite with the rootstocks, 22 produced apparently healthy trees and 5 gave infected trees, though the symptoms were less severe than in the 26 trees raised from unheated control buds. The health status of the trees thus produced from heat-treated trees was checked by grafting five buds from each tree singly onto M.XXV rootstocks known to be free from rubbery wood virus and examining the resulting trees for rubbery wood symptoms when two years old. All of the trees that appeared healthy in the first test produced healthy progeny, while the five slightly rubbery trees produced severely affected progeny with rubbery wood characteristic of this strain of the virus before heat treatment.

Vein yellows and bark necrosis of pear

A strain of Williams' Bon Chrétien pear that is graft-compatible with Quince A rootstocks (6) was heat-treated as the clone was infected with both vein yellows and bark necrosis viruses.

In early May 1957 young potted trees of the infected Williams' were placed in an incubator maintained at $37 \pm 2^{\circ}$ C. After four weeks' treatment, soft tips (1–1·5 cm in length) of extension shoots produced in the incubator were cleft-grafted onto young pear seedlings. The tops of the grafted plants were enclosed in polythene bags and shaded from direct sunlight. Three weeks later, when many of the grafts had united and the young scions had begun to grow, the polythene bags were removed. By the end of July ten of the grafts had made about 30 cm of growth and five buds from each were grafted singly onto Quince A rootstocks in the nursery, buds from two sticks of untreated Williams' being grafted as controls. The following year all of the Williams' budlings from six of the heated tips were free from vein yellows, while progeny from four of the heated tips and from the two unheated control bud-sticks were infected. Six of the healthy trees (one derived from each tip) were retested by grafting five buds from each tree onto Quince A rootstocks. All of the resulting trees were free from vein yellows.

The original trees that were heat-treated and from which these healthy plants were propagated developed symptoms of vein yellows.

Seven of the plants propagated from heat-treated tips were tested for the presence of bark necrosis virus by graft-inoculations to the sensitive quince indicator C7/1. Six of these Williams' plants were free from vein yellows and one was infected ; two unheated plants were included as controls. After one year's growth, none of the buds from the six plants free from vein yellows had induced bark necrosis on the C7/1 indicator plants, but symptoms had developed on the indicators inoculated with the buds infected with vein yellows.

Quince stunt virus

One-year-old plants of Quince C growing in pots were placed in an incubator at 37±2° C during August 1958. After four weeks, buds from these plants were grafted onto healthy Quince A rootstocks. Twenty-four Quince C scions grew and were tested when one year old for the presence of quince stunt virus by graft inoculation to the sensitive quince C7/1. All of them were found to be infected with quince stunt virus.

Further attempts were made to inactivate quince stunt virus by immersing Quince C budwood in water at 50° C for periods of from 5 to 15 min. Immediately after treatment the buds were grafted onto quince or pear seedling stocks. Bud-shields treated for 15 min. united with the rootstocks, but only those buds grew which had been treated for eight min. or less. The virus was not eliminated from any of the buds, nor from the bud-shields that had been treated for 15 min.

In another experiment young soft tips cut from Quince C plants that had made rapid growth during 11, 15, 21 or 30 days' treatment in an incubator at 37° C were either cleft-grafted onto the tips of young quince or pear seedlings, or were rooted under mist. Fourteen tips were successfully grown, and 12 of these induced typical symptoms of quince stunt virus when graft-inoculations were made to quince C7/1 indicators. One tip (30 days' treatment) induced mild symptoms reminiscent of those caused by quince stunt virus, while another (11 days' treatment), was apparently virus-free.

Discussion

Rubbery wood virus is widespread in several apple varieties in Europe ; most trees tested of Michaelmas Red and Golden Delicious, for example, have proved to be infected. Vein yellows is even more prevalent in pear than rubbery wood in apple, and many varieties appear to be totally infected. The high proportion of healthy Lord Lambourne and Williams' Bon Chrétien trees propagated from heat-treated trees that were previously infected suggested that this method would be less time consuming and more rewarding than indexing large numbers of trees to find one that is virus-free. It also suggests a reason why rubbery wood virus either is absent or symptoms are not expressed in areas with high summer temperatures such as Australia and the mid-western states of the U.S.A.

A curious feature of the rubbery wood virus inactivation was the mild degree of rubbery wood in trees grown from five of the heat-treated buds, and the recurrence of more severe symptoms in trees grown from buds cut from these mildly affected trees. The virus concentration in the heat-treated buds was probably low, but this seems unlikely to have affected symptom expression since an interval of nine months elapsed from the time the buds were grafted onto the M.II rootstocks until they began to grow the following spring, by which time the virus should have reached its normal concentration. A possible explanation is that non-virulent strains of the virus are more tolerant of high temperatures than virulent strains ; during heat treatment non-virulent strains may become dominant and subsequently delay the multiplication of more virulent strains.

The simultaneous elimination of vein yellows and bark necrosis from the Williams' pear may suggest that these are different symptoms caused by one virus. This seems improbable, however, as other clones have proved to be infected with bark necrosis virus but not with vein yellows.

The single Quince C plant obtained apparently free from the quince stunt virus has been propagated for further virus tests and for trials as a rootstock for pear. It has supported a quince C7/1 scion for a year during which excellent growth without symptoms has occurred, whereas C7/1 usually fails to grow on Quince C, or produces only a rosette of puckered leaves (3). If further tests confirm that this plant is virus-free, the performance of the clone derived from it will be interesting compared with infected Quince C, which is the most dwarfing and precocious rootstock available for pears.

Summary

Apple rubbery wood, pear vein yellows, quince bark necrosis and quince stunt viruses were inactivated in buds or the tips of young shoots by growing infected plants at 37° C. Healthy plants were raised from diseased plants by propagating these tissues.

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FURTHER STUDIES OF THE INFLUENCE OF OIL-EMULSION SPRAYS ON BUD-INFECTIONS OF APPLE MILDEW

By M. H. MOORE, MARGERY BENNETT, and R. T. BURCHILL

Experiments on M.III apple rootstocks from 1954 to 1958 showed that a mean reduction of about 60% in the incidence of mildewed leaf-trusses and shoots in spring was obtained by spraying to run-off with dinitro-*ortho*-cresol (DNOC)*/petroleum-oil emulsion (0·1% DNOC and approx. 3% petroleum oil) at the bud-swelling stage (4). The experiments were not designed to show the influence of either of the main spray-components separately, nor was it known whether spraying at some other period would not be equally effective. The mode of action of the spray also was obscure. Further experiments were therefore designed to investigate these issues, and the results are reported below.

Materials and methods

During 1958-61, separate experiments, each based on DNOC/petroleum applied at bud-swelling, were conducted on two 320 ft E–W rows of unworked M.III rootstocks grown as hedges. The treatments, started in winter 1958–59, were as follows :

Experiment A

(1) DNOC/petroleum-oil emulsion
(2) DNOC and spreader
(3) Petroleum-oil emulsion
(4) Unsprayed controls

} applied in March at the bud-swelling stage.

Treatments were randomized on 16 ft plots with 5 replicates.

Experiment B

(1) DNOC/petroleum-oil emulsion applied at bud-swelling.
(2) DNOC/petroleum-oil emulsion applied in December.
(3) Tar-oil emulsion applied in December.
(4) Unsprayed controls.

Treatments were randomized on 13 ft plots with 6 replicates.

As DNOC/petroleum was included in Experiment B at the normal time for tar-oil spraying, tar-oil emulsion was included for comparison.

Spray materials

DNOC/petroleum-oil emulsion.—A commercial preparation was diluted to 4½% by volume to give a spray containing 3% petroleum oil and 0·1% DNOC.

DNOC in wetter.—DNOC was dissolved in diacetone alcohol and a non-ionic wetter (Lissapol NX) added. When diluted the spray contained 0·1% DNOC and 0·025% wetter.

Petroleum-oil emulsion.—A commercial preparation was diluted to 4½% by volume to give a spray containing 3% petroleum oil.

Tar-oil emulsion.—A commercial preparation was diluted to 5% by volume to give a spray containing 3% anthracene oil.

All sprays were applied to run-off with a 2 h.p. mobile machine supplying a twin-nozzle lance. During the drying period the oil sprays, especially those containing petroleum, were retained conspicuously around the buds, but the DNOC/wetter spray formed a thin, even film over buds and twigs alike. The rate of drying varied greatly, up to several hours according to weather conditions ; the petroleum-oil sprays usually dried more slowly than the others.

Detailed observations of mildew development on the opening leaves were made on sections of an additional row of M.III sprayed with the materials compared in Experiment A.

Records

The number of mildewed buds and shoots on each plot was recorded in April or early May every year, and the number of buds showing restricted or unrestricted mildew development on the first-expanded leaves was noted for each treatment on the additional row.

* According to the 1961 revision of British Standard 1831, the recommended common name of this compound is DNOC.

The rate of bud-development was recorded on several occasions in spring by means of a range of increasing category values :

Category	*Stage of bud-development**
1	up to breaking
2	breaking to burst
3	burst to early green-cluster
4	early to late green-cluster
5	wood-bud leaves expanding
6	extension shoots growing
7	plots uniformly green

Results

The effects of the sprays in controlling mildew in 1959–61 are shown in Fig. 1, and their influence on bud-development (3-year means) in Fig. 2. The differential effects on bud-stimulation of the times of application of DNOC/petroleum, and of tar oil applied in winter, are illustrated in Fig. 3.

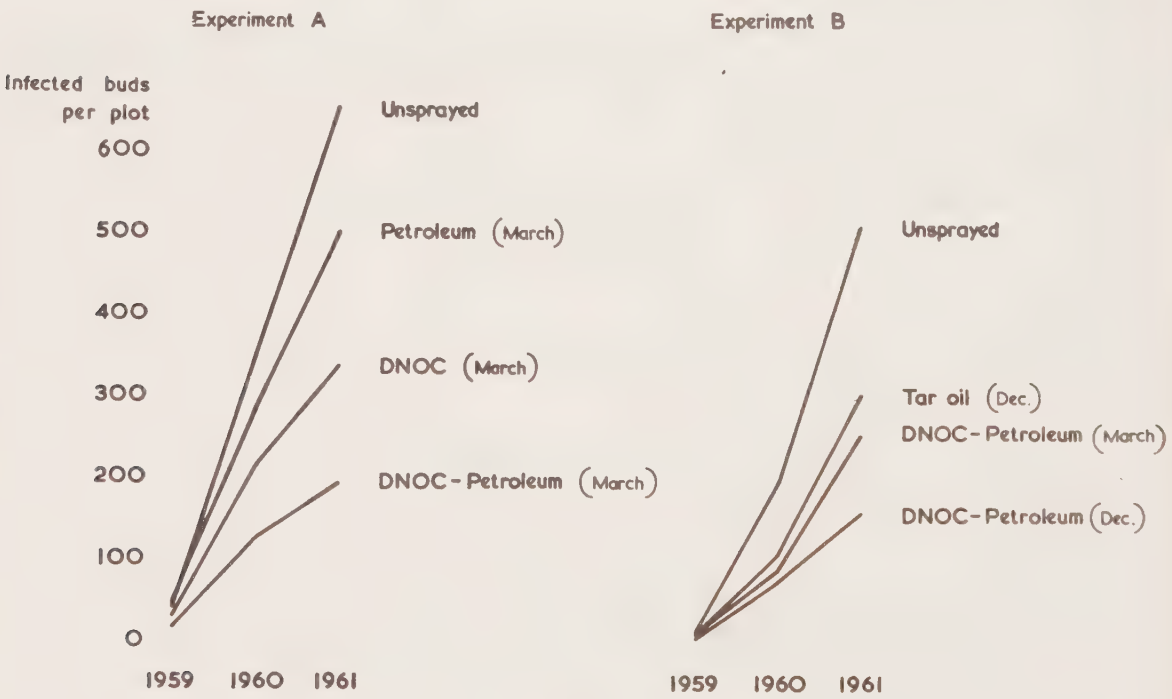

Fig. 1

Effects of sprays in reducing primary mildew development in spring

Discussion and conclusions

Fig. 1 shows that the effects of the sprays diverged as levels of infection increased from one year to the next. An increase was to be expected, as secondary foliar mildew remained uncontrolled each year during the growing season. In Experiment A, DNOC alone was much more effective (sig. at 1% in 1959 ; 0·1% in 1960–61) than petroleum oil alone (sig. at 1% in 1960 ; 0·1% in 1961) in repressing the development of mildew. In Experiment B, treatments had a significant effect in 1959 (5%) and 1960–61 (0·1%) ; tar oil reduced the incidence of mildew but DNOC/petroleum was superior, especially when applied in December. Although the risk of bud-sealing from petroleum oil is usually increased by spraying during dormancy, especially in windy weather, the risk from 3% of oil is much less than it would be from 6% of oil, hitherto recommended chiefly for apple-capsid control (6).

Winter application of DNOC/petroleum stimulated the buds in spring, but spring application

* According to Min. of Agric. Bull. No. 137.

initially retarded their development (Figs. 2, 3). In Palestine, Samisch (5) also found that winter application stimulated apple buds, and spring application controlled irregular bud-break (common after mild winters) by reducing the number of those that remained in the resting stage. Late bud-development may well be allied to greater regularity in breaking.

The effects of the spray as an anti-mildew agent are seen in restricted mildew development on leaves expanding from infected buds. In untreated buds the leaf-initials become covered with the fungus at a late stage before the buds burst, and hence the unfolding leaves are usually entirely mildewed from the outset (2). In the present experiments, microscopic examination of infected buds spring-sprayed with DNOC/petroleum (Experiment A) showed that the distribution of the fungus within the buds remained localized. Thus when mildew infection later became apparent on the

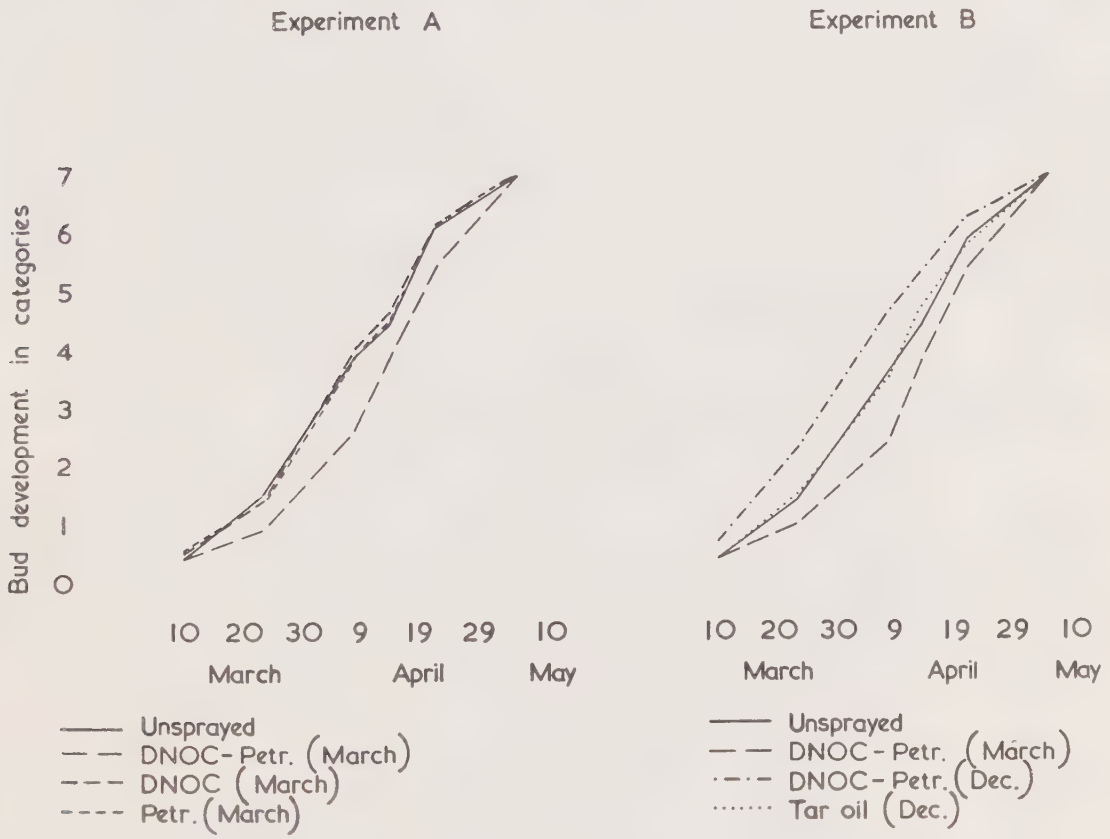

Fig. 2

Effects of sprays in stimulating or initially retarding bud-development in spring

expanding leaves it was patchily distributed ; moreover, its subsequent progress failed to match the rate of leaf development, and the younger leaves thus escaped infection. Counts per unit area of conidia recovered from leaves emerging from these buds further showed appreciably lower values than those from unsprayed buds. Thus mildew-restriction coupled with lowered spore-production would reduce the supply of spring inoculum.

The precise mode of action by the spray within tightly-closed buds remains problematic, but clearly the inclusion of DNOC is essential to maximum effect. Possibly it penetrates the buds from a surface deposit sufficiently to inhibit the development of the fungus without killing it. The limited effectiveness of tar and of petroleum oil may depend upon action of possibly a different kind. If either oil penetrated to the meristematic bud tissues, severe injury would probably result. There was no evidence of it in the buds examined, though oil penetration of imperfectly-closed, infected buds might be feasible, and in practice could account for some reduction in primary mildew by the killing of buds not already killed by the fungus. In these experiments, however, such killing (7) played at most only a minor part.

The merits of DNOC/petroleum for control of mildew were not recognized when this spray was widely used as an insecticide in the apple spray programme ; mildew was not then a disease of first importance owing largely to the regular use of sulphur sprays in spring and summer. In Germany, Junker (3) had, however, reported a reduction in gooseberry mildew (*Sphaerotheca mors-uvae*) following a bud-swelling application of lutin (DNOC). Similarly tar oil, though not highly effective in the present experiments, was effective enough to suggest that its regular use in the past for aphid control probably contributed to the suppression of mildew. This attribute of tar oil also passed unnoticed in England, but in France Bougard (1) was recommending carbolineum sprays for mildew control.

Thus to the more obvious reasons usually advanced to explain the recent mildew epidemic—including the change from spur pruning to renewal and regulated pruning, and from sulphur to organic sprays for scab—must now be added the abandoning of winter-oil sprays. Nevertheless, whether or not to take advantage of the mildew-repressing property of DNOC/petroleum must clearly depend upon careful consideration of its cost in relation to its likely contribution to the insecticide and fungicide spray-programme as a whole. For instance, in a long-term experiment on Cox's Orange Pippin in which regular spring and summer applications of lime-sulphur were made, mildew was satisfactorily controlled throughout the epidemic years where DNOC/petroleum was omitted. By contrast, where captan was used as the spring and summer spray, DNOC/petroleum applied at bud-swelling was as effective as in the present experiments in reducing primary mildew at the beginning of each season (unpublished data). On trees that can conveniently be pruned, however, to cut out the mildew carefully in winter and spring would probably provide a more certain clean start to the season than to spray with DNOC/petroleum. Where such spraying is selected as an economic supplementary measure for mildew control, thorough high-volume application may be advisable ; low-volume spraying might fail to cover the buds sufficiently to give good results.

Acknowledgements

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Summary

These experiments confirm earlier findings that to spray M.III apple rootstocks at bud-swelling with DNOC/petroleum emulsion of 0·1% DNOC and 3% oil substantially reduced primary mildew from overwintering infection in the buds. To spray in December was, however, more effective. Tar oil also gave appreciable control, but was less effective than DNOC/petroleum, of which DNOC was the more active component. Spring application of DNOC/petroleum initially retarded, and winter application accelerated spring bud-development.

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Fig. 1.

Spring bud-development on M.III rootstock hedge after spraying (Experiment B) with : (1) DNOC petroleum in March (retarded buds) (2) DNOC petroleum in December (stimulated buds) (3) tar oil in December (as unsprayed). (4) Unsprayed controls (normal bud development)

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Fig. 1

Above: Leaves from Daniels' September, naturally infected

Below: Leaves from open pollinated Baldwin seedlings inoculated from variegated Daniels' September

TRANSMISSION OF VARIEGATION IN BLACK CURRANTS

By CHRISTINA E. ELLENBERGER

In describing two virus diseases of black currants in 1952, Posnette (1) referred to a variegation of the variety Daniels' September as ' probably not transmissible '. This conclusion was reached because plants of Wellington XXX and Baldwin had failed to develop symptoms when chip-grafted with affected scions ; it has now been shown, however, that this variegation is, in fact, graft-transmissible.

All plants of Daniels' September seen by the writer showed a pale yellow or white mosaic on the mature leaves and a yellow vein-banding on the leaves formed in summer ; this symptom is known to be widespread in this variety. Similar symptoms were recorded in the varieties Nigger, Laleham Beauty, Boskoop Giant, Blacksmith, Seabrook's Black and Mendip Cross.

Transmission tests

In August 1956, five seedlings grown from open pollinated Baldwin seed sown early that year were inoculated by grafting into them petioles from variegated leaves of Daniels' September. In the following year the five seedlings developed variegation while the uninoculated controls remained normal. Variegation was also transmitted when black currant seedlings were chip-grafted with scions from a Seabrook's Black bush having symptoms similar to those shown by Daniels' September.

To investigate the tolerance of Wellington XXX and Baldwin suggested by Posnette's tests, two bushes of each variety were grafted with chip-scions from (*a*) a Baldwin seedling infected as described above, (*b*) a Daniels' September plant and (*c*) a Nigger plant naturally infected with variegation.

These bushes were three years old when inoculated in 1957 and none had developed symptoms by the end of 1959. After severe pruning in the spring of 1960, one of the Baldwin seedlings grafted with Daniels' September developed slight variegation on the new growth. The prunings were propagated to provide 10-12 rooted cuttings from each bush. One of these cuttings, from a Wellington XXX bush inoculated with scions from Daniels' September, developed variegation in 1961, and six Baldwin and four Wellington cuttings from the Nigger-inoculated bushes showed symptoms in 1960, but not in 1961.

Discussion

The tests established clearly that black currant variegation is graft-transmissible and that the failure to record transmission in previous tests was due to the tolerance of both Baldwin and Wellington XXX to the virus. The sporadic occurrence of the disease in other varieties indicates the presence of a vector. Inoculation with expressed sap has failed so far to transmit the virus to herbaceous hosts, so that field spread by pruning seems unlikely to occur. The virus may, however, be widespread in tolerant varieties, such as Wellington XXX and Baldwin, which show only transient symptoms. Stock bushes used for commercial propagation should, therefore, be tested by grafting to young black currant seedlings.

Summary

Yellow variegation and vein-banding occur in several varieties of black currant and are prevalent in Daniels' September. Seedlings derived from open pollinated Baldwin developed conspicuous symptoms in the year following inoculation by grafting, but clonally propagated Baldwin and Wellington XXX were found to be tolerant and showed only slight, transient symptoms.

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MACHINE PICKING IN RELATION TO PROGRESSIVE VERTICILLIUM WILT OF THE HOP

II. THE EFFECT OF COMPOSTING ON THE INFECTIVITY OF MACHINE-PICKED HOP WASTE

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Even when hop gardens are regularly inspected and all wilting plants removed, many symptomless, infected plants may escape detection and be harvested for machine-picking. In all hop gardens in wilt-affected areas, the waste matter accumulated in the vicinity of the picking machine is likely to be highly infective and consequently potentially dangerous for the spread of progressive verticillium wilt (4).

Burning is the safest method of disposing of infested hop waste, but this may often prove impracticable because of unsuitable weather conditions or site factors. In the absence of a convenient and safe site for depositing the waste (such as a quarry) the only remaining alternative, and the one most commonly adopted, is to compost it and subsequently spread it on land cropped with plants which are not sensitive to verticillium wilt. If *Verticillium albo-atrum* survives the composting treatment, this practice could result in widespread symptomless infections of crops and weeds (3), and the land thus treated would become a persistent source of inoculum from which neighbouring hop gardens could become contaminated.

Although Keyworth (1) reported a case where hop bines were still infective after a form of composting, preliminary results from a joint study of this problem with the Department of Hop Research, Wye College, suggested that infested hop waste might be rendered wholly or largely innocuous if composting was done efficiently : thus from studies of temperatures in hop waste compost heaps by D. G. Martin (unpublished), and other investigations (5), it is now known that temperatures lethal to *V. albo-atrum* may be reached in all but the outer layers of compost heaps. Phillips (2), working with tomato stem rot (*Didymella lycopersici* Kleb.), obtained adequate heating of these outer layers by repeatedly turning and mixing the composting mass. Since there are objections to treating hop waste in this way, a commercial compost heap was chosen for study which was so made that heat loss from the outer layers would be minimal.

The objects of the present investigation were : (i) to obtain direct information on the destruction of *V. albo-atrum* in infested hop waste during composting, (ii) to determine whether destruction was related solely to temperature, or whether microbial antagonism was involved, and (iii) to determine whether localized spread of *Verticillium* occurred within the compost mass by the contamination of healthy hop residues.

Material and methods

The method of composting

The hop waste was deposited in an enclosure constructed alongside the picking machine shed. One side wall of the shed was replaced by a 6 ft high wall of concrete blocks, and one end wall was built with the same material. The outer side wall was left as a bare earth bank topped by two layers of straw bales laid flat. Later the open end was closed with a wall of straw bales. A layer of straw 6-9 in. deep was spread over the floor of the enclosure. The enclosure was 60 ft long and 20 ft wide and decreased in depth from 6 ft at one end to 3 ft at the other because of the natural slope of the ground.

Chopped, machine-picked hop waste was dropped from a conveyor which projected from the picking machine directly over the centre of the composting enclosure. In the early stages the waste was pushed to one end of the enclosure by bulldozer and later spread by hand. The enclosure was filled by 28th September, when it contained the chopped waste from 30 acres of hops (about 150 tons). The whole surface of the waste was covered with 6 in. of loose straw ; half the area was then covered with a single layer of 200 gauge polythene sheet, and the whole surface was then covered with straw bales. The composting mass was sealed on 2nd October.

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Burial of test hop waste samples

The four types of hop waste used in this investigation were clean and *Verticillium*-infested bine lengths (3-4 in.), and clean and *Verticillium*-infested chopped trash which consisted almost entirely of thin lateral branches. Aliquots of each type of bine and trash, weighing respectively 1 lb and 4 oz, were packed in double-thickness nylon stocking bags and buried in the compost on 19th October. Bags of *Verticillium*-infested bine and trash were also stored dry in the laboratory so that their infectivity could later be compared with that of the composted samples.

A pit, 30 in. square, was dug to a depth of 36 in. below the surface of the compost. Nylon bags containing the four types of hop waste material were placed on the floor of the pit, so that bags of *Verticillium*-infested material touched and alternated with bags of clean material. Each bag was connected to a length of galvanized wire which protruded above the compost surface to facilitate subsequent recovery. A conduit tube was placed vertically in the pit, touching the bottom and protruding above the surface, thus enabling temperatures at the point of burial to be taken by thermometer. The pit was then refilled to a level 18 in. below the compost surface, where a second layer of samples and a thermometer tube were similarly placed. After burial of the second layer, samples were placed on the surface of the pit and compost, and the insulating materials were replaced.

A total of three sets of test samples were buried in this manner—one centrally in the area of compost which was covered with polythene sheeting and straw bales, and the other two in the area covered only with straw bales.

Recovery and method of testing infectivity of hop waste samples

All bags of hop waste were retrieved from the compost on 16th March, 21 weeks after burial, and were placed separately in polythene bags to prevent subsequent contamination. The field trial to test the infectivity of the composted waste was set up during the next three days as follows :

The total contents of one bag of trash (4 oz) were placed beneath a layer cut of Fuggle N on planting and the contents of one bag of bine (1 lb) were distributed evenly between four plants. The planting was in randomized plots separated by gaps of 8 ft and 12 ft respectively in rows and alleys, with 2-ft gaps between plants.

Temperatures within the compost

Temperatures were recorded by thermometers which rested within the open-ended plastic tubes connecting each of the nine burial positions with the surface. The thermometer bulbs were insulated with plasticine to prevent rapid changes of temperature during recovery of the thermometers. Temperatures were taken at weekly intervals for the first three weeks and thereafter fortnightly. These records

TABLE I

TEMPERATURE READINGS (°C) AT SITES OF BURIAL OF TEST HOP WASTE IN THE COMPOSTING MASS

Site	Depth of burial (in.)	Date (1960-61)											
		25 Oct	1 Nov	8 Nov	27 Nov	6 Dec	20 Dec	3 Jan	17 Jan	31 Jan	14 Feb	28 Mar	16 Mar
1 (*a*)	0	38	32	35	38	24	**50**	36	**46**	31	**61**	**45**	**48**
	18	**60**	**54**	**52**	**47**	**70**	**50**	**48**	**46**	33	**60**	**45**	**45**
	36	**59**	**54**	**58**	**48**	**70**	**47**	**52**	**45**	37	**50**	44	42
2 (*b*)	0	34	26	23	22	24	23	15	19	14	34	19	19
	18	**61**	**56**	**62**	**49**	**54**	44	40	42	33	**45**	38	42
	36	**52**	**56**	**57**	**49**	**55**	42	38	38	43	**50**	44	39
3 (*b*)	0	**56**	**50**	**47**	42	30	29	22	18	17	29	22	23
	18	**68**	**67**	**59**	**46**	**46**	29	32	30	27	43	34	33
	36	**51**	**57**	**59**	**46**	**54**	40	32	29	33	38	37	33

(*a*) Compost surface covered with loose straw, polythene sheet and straw bales.
(*b*) Compost surface covered with loose straw and straw bales.

NB. Figures in bold print are temperatures lethal to *V. albo-atrum* if sustained for at least 12 hours.

are shown in Table I, where figures in bold print represent temperatures sufficiently high to kill *V. albo-atrum* in hop bine, if sustained for a minimum period of 12 hours (5). The sudden temperature rise during February is probably associated with the improved drainage from the compost which was effected about this time.

Temperatures lethal to *V. albo-atrum* were recorded at 18 and 36 in. depth throughout the seven-week period following burial of the test samples, and for a further six weeks in the polythene-covered area of compost (Site 1). Temperatures at the surface of the compost were rather erratic and generally low but lethal levels were reached at two of the three sites : polythene cover did not promote sustained high temperature at the surface as it appeared to do at greater depths.

It should be noted that hop waste samples were not buried until three weeks after the compost enclosure had been filled, and that this important period of initial fermentation, when compost temperatures are highest, was not included in the experiment.

Results of the infectivity trial of composted hop waste

The test plants were inspected frequently, and as soon as definite wilting occurred they were cut down and carefully removed from the plot. The first wilt symptoms were recorded on 20th June. On 19th October all bines were cut near soil level and examined for vascular discoloration, and wood from suspect bines was tested for the presence of *Verticillium* by culturing on agar medium.

The results of this trial are summarized in Table II, where the results for hop waste samples from the three burial sites have been combined.

TABLE II

INFECTION OF FUGGLE N BY *V. ALBO-ATRUM* AFTER PLANTING OVER COMPOSTED AND NON-COMPOSTED SAMPLES OF *VERTICILLIUM*-INFESTED AND CLEAN HOP WASTE

Treatment of inoculum	Inoculum	Depth of burial (in.)			Totals
		0	18	36	
Composted	*Verticillium*-infested bine *Verticillium*-infested trash	0/32* 1/9	0/24 0/6	0/24 0/6	1/101
	Clean bine Clean trash	0/28 0/6	0/24 0/4	0/24 0/4	0/90
Not composted (Stored dry)	*Verticillium*-infested bine *Verticillium*-infested trash	24/24 3/3			27/27
—	Uninoculated	0/20			0/20

* Number of plants infected by *Verticillium*/number tested.

Non-composted *Verticillium*-infested bine and trash remained infective after 21 weeks' storage and caused wilt and death of all Fuggle indicator plants. In the composted infested waste *Verticillium* was destroyed in all samples except one (of trash) which was sandwiched between the compost surface and the insulating layers of loose and baled straw at Site 2. Although this was the only burial position at which lethal temperatures were not recorded (Table 1), three bags of bine and two of trash from this same position had lost infectivity : thus, while lethal temperatures may have been reached for a brief period and not recorded, it remains possible that *Verticillium* in these samples was destroyed by the action of microbial antagonists.

Clean bine and trash buried in compost in contact with infested samples did not become infective.

Discussion

The highly infective nature of non-composted and inadequately composted hop waste from wilt-affected farms has been demonstrated previously (1, 4). The present investigation indicates that *V. albo-atrum* in hop waste can largely be destroyed in enclosed and insulated compost heaps when lethal temperatures are reached, and perhaps also, to a lesser extent, by microbial antagonism at sub-lethal temperatures. The investigation has further demonstrated that *Verticillium*-free tissues are unlikely to be rendered infective by passive or active saprophytic spread of the pathogen, even when such tissues rest in close proximity to infested waste.

After composting, however, a very greatly reduced level of infectivity is likely to persist in tissues in the periphery of the compost heap. Whilst heat insulation will ensure that survival in this zone is low, it is improbable that complete eradication of *Verticillium* can be accomplished without turning the mass during the early stages of composting, or perhaps by incorporation of the peripheral layers into the following year's compost.

In view of the highly infective nature of hop waste issuing from the picking machine, the system described seems particularly efficient in that the waste is deposited into a compost enclosure situated immediately alongside the machine shed. No further transportation is required until the waste is rendered largely innocuous by composting, and the danger of spread of wilt is consequently very greatly reduced. This study indicates that adequate drainage from the insulated compost and perhaps also protection from rain with polythene sheeting would aid in achieving and sustaining high temperatures.

The spread of hop verticillium wilt takes place largely by the colonization of aerial parts of the plant and their subsequent transportation by human and physical agencies : localized spread from transported tissues may occur later by water dispersal of spores produced on them. The colonization of aerial parts increases as plants become senescent at the end of the growing season ; consequently after hand-picking, when bines are coiled and left *in situ* in the hop garden, much of the leaf and lateral branch material will become colonized and then shed from the main bines before these are collected and burnt. In this way a considerable mass of *Verticillium*-infested tissue is scattered within the hop garden, and may later be carried to other gardens or farms to give rise to new infections.

The advent of machine picking has given rise to some concern that the danger of spreading progressive wilt may be increased. In some circumstances this may be true, but if adequate precautions are taken, the danger can be reduced to a level far below that which is possible when hops are hand-picked.

Assuming that gardens are frequently inspected and all wilting hills removed at an early stage of symptom expression, no wilting plants and very little infested debris will be present at picking time. All aerial tissues, both healthy and infected, are then removed completely from the garden and transported to the picking machine while green and intact. Provided that loose debris in the gardens and along farm and public roads is collected and burnt, virtually all *Verticillium*-infested aerial tissue is accumulated as waste near the picking-machine site. Incineration of this waste will destroy all *Verticillium* in it ; alternatively, by depositing the waste into an insulated compost enclosure, the level of infectivity can be greatly reduced.

Even when an efficient composting procedure is used it remains advisable to restrict the use of the hop compost, which is comparable in value to farmyard manure, to grassed orchards of apple, pear or cherry. The compost should not be used on potato or strawberry land, nor on any area which may later be planted with hops.

Acknowledgement

We are grateful to Mr. A. B. Scripps, for his kind co-operation during part of this investigation.

Summary

Samples of *Verticillium*-free and infested hop waste were buried in an enclosed, insulated, composting mass of hop waste on a commercial farm. Temperatures were recorded regularly at all test burial sites in the compost. After 21 weeks' composting, the infectivity of all samples was tested in a field experiment using Fuggle N plants as indicators.

V. albo-atrum was destroyed in 99% of the infested samples. *Verticillium* survived in a single sample taken from the compost surface, immediately beneath the insulating layers : this was the only burial site at which lethal temperatures were not recorded, and the destruction of *Verticillium* in other samples from this site suggested that the action of microbial antagonists might here be involved. *Verticillium*-free samples in contact with infested waste during composting did not become infective.

To achieve the sustained high temperatures necessary to kill *Verticillium*, the compost mass should be of minimum surface area, insulated against heat loss, and adequately drained. A permanent composting enclosure, constructed beside the picking-machine shed, is particularly satisfactory for minimizing handling of the waste before it is rendered largely innocuous by composting. It is improbable that *Verticillium* can be eradicated completely without turning the composting mass to ensure that waste from the peripheral zone is subjected to high temperatures.

Measures to minimize the danger of spreading progressive wilt are recommended : it is considered that machine picking offers a greater potential opportunity for controlling spread than is possible with hand picking. Inadequate precautions, however, could lead to increased spread.

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ENTOMOLOGY

PHYTOTOXICITY RESULTING FROM FOLIAR APPLICATIONS OF FLUOROACETAMIDE TO BLACK CURRANTS

By G. H. L. DICKER and R. P. TEW

The discovery (1) that fluoroacetamide possessed marked biological activity against the black currant gall mite, *Phytoptus ribis* (Nal.), led to a series of trials to assess its value for field control. Arising from these, Collingwood, Vernon and Legowski (2) reported some loss of fruit following a post-blossom application at a concentration of 0·05% and also poor rooting of cuttings that were dipped in a 0·5% solution.

At East Malling, in 1959, mild but obvious chlorosis, accompanied by indications that yield was also affected, aroused doubts regarding the safety of this chemical on black currants and further work on this aspect was undertaken in 1960.

Materials

Experiments were carried out on the varieties Baldwin and Wellington XXX, using the following chemicals:

fluoroacetamide as an aqueous solution, and *Thiodan*, 6,7,8,9,10,10-hexachloro-1,5,5a,6,9,9a-hexahydro-6,9-methano-2,4,3-benzo[*e*]-dioxathiepin 3-oxide, as an emulsifiable concentrate.

Both were applied as drenching sprays at 0·05%, with 0·02% dioctyl sodium sulphosuccinate added as wetter.

Effects on foliage

Young leaves, only partially expanded at the time of spraying, developed a marginal chlorosis which often later extended over the entire lamina and persisted for about four weeks. These leaves also showed slight cupping with the apices more rounded and irregular than on normal ones, and appeared to be smaller. Symptoms, clearly visible on Baldwin but only just discernible on Wellington XXX, appeared on all occasions on which 0·05% fluoroacetamide was applied ; the chlorotic effect was accentuated by a concentration 0·1% but was not detected when 0·025% was used.

Effect on yield

1959 trial

This trial was planned primarily to provide fruit for determination of harvest residues. Sprays were applied at the beginning of the blossom period, 3rd April (A), at the end of flowering, 1st May (B), and on both occasions (A and B), there being three single bush replicates of each variety.

Approximately equal amounts had been picked from each bush before the fruit ripened. At the harvest period smaller fruits were observed on those bushes of Baldwin which had been sprayed with fluoroacetamide. Records of weight and berry size of the fruit remaining on this variety are given in Table I. By this date all fruit of Wellington XXX had been picked.

TABLE I

CROPPING OF BALDWIN FOLLOWING SPRAYS APPLIED AT THE BEGINNING (A) AND AT THE END (B) OF THE BLOSSOM PERIOD

	Unsprayed	0·05% Thiodan			0·05% fluoroacetamide		
		A	B	A+B	A	B	A+B
Weight per bush (lb)	6·6	6·5	7·0	7·4	5·6	5·6	4·5
No. of berries per ½ lb	388	340	375	336	395	490	520

These results suggested that Thiodan had no influence on cropping but that the use of fluoroacetamide was associated with a possible adverse effect on yield and fruit size. This led to a further trial with the latter chemical in 1960.

1960 trial

The same bushes were used as in 1959, the treatments being re-randomized to give six single bush replicates of each variety. Sprays were applied as before on 13th April (A), 17th May (B), and on both occasions (A+B).

Crop records (Table II) included the weight per bush and the number of berries in a half-pound sub-sample ; from these data the number of berries per bush was calculated.

TABLE II

THE EFFECT ON YIELD OF 0·05% FLUOROACETAMIDE WHEN APPLIED AT THE BEGINNING (A) AND AT THE END (B) OF THE BLOSSOM PERIOD

Treatment	Wellington XXX			Baldwin		
	Wt per bush (lb)	No. of berries		Wt per bush (lb)	No. of berries	
		per ½ lb	per bush		per ½ lb	per bush
Unsprayed	6·7	221	3002	6·3	288	3609
A	6·3	278	3464	5·4	369	3950
B	4·1	292	2403	6·0	359	4286
A+B	3·1	354	2136	2·3	373	1667
Significance levels						
A	—	·01	—	—	·01	—
B	·001	·001	·01	—	·05	—
Interaction	—	—	—	·01	—	·001

On Wellington XXX, treatment B reduced the yield ; treatments A and B increased the number of berries per half-pound sample, i.e. reduced the size of the berries, and treatment B reduced the total number of berries per bush. There was no interaction between treatments.

On Baldwin, treatments A and B reduced berry size ; neither treatment affected yield or total number of berries per bush, but the combination resulted in a considerable reduction of both. The origin of this effect was not clearly evident but it could have been associated with the foliage symptoms which were more severe on Baldwin than on Wellington XXX.

Conclusions

The indication (Table I) that fluoroacetamide affected berry size in 1959 was confirmed in 1960 (Table II). Of the two applications, the one at the end of the blossom period (treatment B) is the more effective for control of black currant gall mite and it was this spray which caused a marked reduction in yield on Wellington XXX as well as reducing the berry size on Baldwin.

Acknowledgements

We wish to thank Miss H. P. Insley and Miss E. J. Basker for taking the crop records and Mr. D. H. Rees for the statistical analyses.

Summary

Applications of 0·05% fluoroacetamide to the varieties Baldwin and Wellington XXX at the beginning or at the end of the blossom period reduced berry size. A reduction in yield resulted from the later spray on XXX and when both were applied to Baldwin. In addition, each spray caused mild chlorosis of the foliage, especially on Baldwin.

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FURTHER STUDIES OF THE TOXICITIES OF FUNGICIDES TO PREDATORY MIRIDS OCCURRING IN APPLE ORCHARDS

By R. C. MUIR

It is known that some of the sprays used for controlling apple scab and mildew may interfere with the predators regulating populations of arthropod pests. Thus Reed (4) has already shown that whereas lime-sulphur was toxic to *Psallus ambiguus* (Fall.), dispersible sulphur at 7 times the normal orchard concentration, and captan at 50 times, had no effect. This paper reports the results of experiments on the susceptibility to a number of fungicides of *P. ambiguus* and of *Blepharidopterus angulatus* (Fall.), predatory mirids that are important in controlling populations of the fruit tree red spider mite, *Metatetranychus ulmi* (Koch) (2, 3).

Materials and methods

Fourth and fifth instar nymphs of *P. ambiguus* and *B. angulatus*, were obtained from the orchard immediately before each experiment, and provided with a culture of *Aulacorthum circumflexum* (Buckt.) as a source of food. As *B. angulatus* hatches 4 to 6 weeks later than *P. ambiguus*, experiments on these two species could not be run concurrently. All experiments were conducted in the laboratory at a temperature of 60–70° F.

The fungicides tested were :

lime-sulphur	a solution containing 24% (w/v) polysulphide,
dispersible sulphur	containing approximately 70% (w/w) sulphur,
colloidal sulphur	50% (w/w) sulphur,
zineb	zinc ethylene-1,2-bisdithiocarbamate (wettable powder),
dodine acetate	dodecylguanidine acetate (wettable powder),
dinocap	2-(1-methyl-n-heptyl)-4,6-dinitrophenylcrotonate (wettable powder),
captan	*N*-trichloromethylthio*cyclo*hex-4-ene-1,2-dicarboxyimide (wettable powder).

Single apple leaves were dipped for 5 seconds, allowed to dry, and then placed in 3 × 1 in. specimen tubes, which were tightly corked to retain any fumes that might be evolved. In one experiment involving a range of volumes of neat lime-sulphur, the leaves were sprayed on both sides while rotating on a turn-table, the spray being delivered by an Aerograph air brush fixed 15 in. away at an angle of 45°. Insects were tested in a similar manner ; each replicate was put in a petri dish lined with filter paper to absorb excess liquid, and sprayed with 1 ml of the fungicide, or with a range of volumes of neat lime-sulphur. Although mirid larvae are normally very active, the rotation of the turn-table kept them quiescent long enough to complete the spraying. The sides of the petri dish were coated with polytetrafluoroethylene to prevent the larvae from climbing out. The spray cover was tested by spraying a check replicate with a sunbonded fluorescent pigment known as ' Neon Red ' which made the deposit visible under ultra-violet light so that its adequacy could be confirmed visually. Only three insects were put in each tube, as under more crowded conditions they are prone to cannibalism.

Three treatment combinations were tested (Table I):

(*a*) treated leaves with treated insects,
(*b*) treated leaves with untreated insects,
(*c*) untreated leaves with treated insects.

These combinations were run concurrently for each species of insect, each treatment being replicated seven times.

Results

Comparison of the toxicities of the fungicides

The results of the experiment comparing the toxicities of the range of fungicides (Table I, Expt.1), revealed that high mortalities of both species occurred only where leaves had been treated with lime-sulphur, the other treatments being innocuous. The captan treatment in the experiment was regarded

TABLE I

PERCENTAGE MORTALITY OF *PSALLUS AMBIGUUS* AND *BLEPHARIDOPTERUS ANGULATUS* 24 HOURS AFTER TREATMENT

Treatments (percentage active) ingredient	*P. ambiguus*			*B. angulatus*		
	Treatment combinations			Treatment combinations		
	Leaves + insects	Leaves only	Insects only	Leaves + insects	Leaves only	Insects only
Exp. 1.						
0·1% captan (control)	0	0	0	0	0	0
2·5% lime-sulphur	95	100	15	65	83	19
0·6% dispersible sulphur	0	0	0	0	4	0
0·6% colloidal sulphur	0	0	0	0	8	5
0·1% zineb	15	0	5	0	0	5
0·1% dodine acetate	0	0	0	0	0	0
0·025% dinocap	0	0	0	0	0	19
Exp. 2.						
Untreated	0	0	0	0	0	0
0·25% lime-sulphur	0	0	0	10	10	0
0·50% ,, ,, ...	0	4	0	5	14	0
1·00% ,, ,, ...	0	9	0	52	52	5
2·00% ,, ,, ...	54	70	0	76	86	5
Exp. 3.						
Untreated	0	0	0	0	0	0
0·05 ml 100% lime-sulphur ..	0	0	7	0	0	0
0·10 ml ,, ,, ,, ..	5	24	7	12	0	0
0·20 ml ,, ,, ,, ..	19	19	27	24	12	47
0·40 ml ,, ,, ..	10	33	20	100	59	35

as a control, and the mortalities occurring in the other treatments were adjusted by Abbot's (1) formula for mortality in this treatment.

The mortality of insects on lime-sulphur treated foliage contrasted markedly with that of insects which had been sprayed and placed on clean foliage. This finding was to be expected as Reed (4) had shown that mirids are poisoned only when lime-sulphur is present in sufficient quantity to liberate a toxic dose of hydrogen sulphide, and mere contact with the chemical need not necessarily be harmful.

The effect of varying the concentration of dilute lime-sulphur

In orchard practice only the earliest applications of lime-sulphur are as concentrated as that included in Experiment 1, and although the conditions of the test were not strictly comparable with those prevailing in the orchard, a further experiment was conducted to compare the effect of decreasing concentrations of lime-sulphur on the mortality of these species (Table I. Expt. 2). With treated leaves, there was a marked increase in mortality, of *B. angulatus* at a concentration of 1% and of *P. ambiguus* at the 2% level, but with insects that had been sprayed and placed on clean foliage there was only a slight increase.

Experiments with concentrated lime-sulphur

The moist films of lime-sulphur that occur on leaves after hydraulic spraying, or after experimental leaf dipping, give off hydrogen sulphide. When, however, lime-sulphur is used as a solution containing 24% (w/w) polysulphide sulphur, in the form of a mist spray, it evaporates so rapidly that, although the sprayed surface receives as much sulphur as in hydraulic spraying, it is hardly wetted at all. It was considered that this reduction of moisture might prevent or at least reduce the evolution of hydrogen sulphide, and thus reduce toxicity ; furthermore, it would also decrease the risk of drowning as a hazard to the delicate mirid nymphs.

Both species of mirid were tested against a range of volumes of concentrated lime-sulphur (Table I, Expt. 3), selected as giving deposits within the range expected from low volume spraying in normal orchard practice ; no attempt was made, however, to measure the deposit except by visual comparison. Lime-sulphur caused some mortality at all levels, and this mortality increased with increasing quantities of lime-sulphur. Thus applying neat lime-sulphur in atomized form did not make it innocuous to

predators, so that atomization has no advantage over hydraulic spraying in the context of predator conservation.

Experiments with dinocap

The low mortality caused by dinocap in Expt. 1 was of interest, because many of the nitrophenols are insecticides. A further investigation was therefore conducted in which insects were sprayed with dinocap (formulated as an emulsifiable concentrate) at concentrations up to 0·4%, 16 times that normally used in orchards ; no increase in mortality was observed.

Toxicity of hydrogen sulphide to nymphs of *P. ambiguus* and *B. angulatus*.

As hydrogen sulphide is considered to be the cause of death of mirid nymphs on leaves sprayed with lime-sulphur, Reed (4) devised a technique for comparing its toxicity at different concentrations. This technique was used in another experiment with fifth instar nymphs of both species. Six concentrations of hydrogen sulphide were chosen between the highest value shown by Reed to be innocuous and the lowest value giving 100% mortality ; from this range of concentrations the 50% lethal dose (LD50) could be obtained. Each concentration was replicated 6 times, and there were 3 insects to each replicate. The number of dead insects was recorded after 2 hours, and the percentage mortality, transformed to probits, was plotted against the logarithm of the concentration. Regression lines were calculated for the resulting scatter of points by the usual method of adjustment by weighting coefficients (1). The LD50 for *P. ambiguus* was found to be 0·0744 μg/ml, with 95% fiducial limits 0·0740–0·0746 μg/ml, and for *B. angulatus* 0·1209 μg/ml, with limits 0·1207 0·1211 μg/ml. Under the conditions of this experiment *B. angulatus* was more resistant to hydrogen sulphide poisoning than *P. ambiguus*, although the former weighed less. When the LD50 was adjusted for body weight, the resulting values were 0·0245 μg/ml/mg body weight for *P. ambiguus* and 0·0917 for *B. angulatus*. The lower susceptibility to hydrogen sulphide of *B. angulatus* compared with *P. ambiguus* is inexplicable and appears to be at variance with the results in Table I, Expts. 2 and 3. In these experiments, whole leaves were treated with lime-sulphur, and although they were chosen for uniformity, they may have differed sufficiently in their capacity for spray retention to account for this apparent anomaly.

Although the LD50 for *B. angulatus* is significantly higher than that for *P. ambiguus*, it is unlikely to account for the former's greater abundance in orchards receiving a modified spray programme. A more likely explanation is to be found in the difference in hatching times of the two species in relation to the spraying schedule. Thus *P. ambiguus* hatches at green cluster and is present not only when the concentration of lime-sulphur is greatest, but also during the whole period of protective spraying; in contrast, *B. angulatus* hatches much later and is exposed to low concentrations only, and few applications. In orchards where highly toxic insecticides are applied pre-blossom and at petal-fall, the early hatching of *P. ambiguus* results in its elimination.

Discussion

Several fungicides appear innocuous to the nymphs of *P. ambiguus* and *B. angulatus* under conditions in which lime-sulphur causes high mortality. These include : dispersible sulphur, colloidal sulphur, zineb, dodine acetate, dinocap and captan, and provide alternatives to lime-sulphur for conserving these predators. Lime-sulphur, however, possesses two advantages, namely that it controls scab and mildew, and is cheap ; its chief disadvantage is its deleterious effect on skin-finish, and for this reason many growers have changed to captan for scab control, combined with dinocap for mildew control, which gives better skin finish although at greater cost. Less expensive competitors with lime-sulphur include dispersible and colloidal sulphur ; these are not as effective as lime-sulphur for disease control, but cause less damage to foliage and to skin finish, and have tended to replace lime-sulphur post-blossom. Either spray schedule, namely captan and dinocap, or lime-sulphur pre-blossom followed by dispersible or colloidal sulphur post-blossom, should spare *B. angulatus*, though *P. ambiguus* is likely to be eliminated where lime-sulphur is used pre-blossom. It remains, however, to test these spray programme modifications in the field before they can be properly evaluated for their influence on predator populations.

Acknowledgement

The helpful collaboration of Mr. R. P. Tew in conducting these experiments is gratefully acknowledged.

Summary

In a series of laboratory experiments to study the toxicity to nymphs of *Psallus ambiguus* (Fall.) and *Blepharidopterus angulatus* (Fall.), of fungicides used for the control of apple scab and mildew, very

low mortality resulted from the use of 0·1% captan, 0·6% dispersible sulphur, 0·6% colloidal sulphur, 0·1% zineb, 0·1% dodine acetate, and 0·025% dinocap, whilst high mortality occurred with 2·5% lime-sulphur.

Dilute sprays containing less than 1% lime-sulphur were harmless, as was dinocap even when applied at 0·4%, 16 times the normal orchard concentration.

Mortality from lime-sulphur when applied to leaves as a concentrate was no less than that obtained with dilute sprays above 1% for *B. angulatus* and above 2% for P. *ambiguus*.

The LD50 of hydrogen sulphide to fifth instar nymphs was found to be 0·0744 μg/ml for *P. ambiguus* and 0·1209 μg/ml for *B. angulatus*.

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PLANT PROTECTIVE CHEMISTRY

THE PERSISTENCE OF CERTAIN ACARICIDES ON APPLE FOLIAGE IN THE FIELD

by R. P. TEW and JOAN M. SILLIBOURNE

Among the acaricides selected for field study in Essex and Kent following the development of tolerance to chlorbenside by the fruit tree red spider mite, *Metatetranychus ulmi* (Koch) (3), were *S*-(2,5-dichlorophenylthiomethyl) diethyl phosphorothiolothionate (phenkapton), 2,4,5,4′-tetrachlorodiphenyl sulphone (Tedion) and 2,2,2-trichloro–1, 1-bis-(4-chlorophenyl)ethanol (Kelthane). The persistence of these chemicals on apple foliage has been followed by chemical analysis.

Methods

Phenkapton

On hydrolysis, phenkapton yields 2,4–dichlorothiophenol. Hardon and his co-workers (5) reported a method for the determination of phenkapton which involves the bromination of this thiophenol, followed by reaction with potassium cyanide, and determination of the cyanogen bromide produced by reaction with a benzidine-pyridine mixture. We were unable to repeat the work of Hardon *et al.* and sought an alternative method. The closely related American acaricide, *S*-4-chlorophenylthiomethyl diethyl phosphorothiolothionate (Trithion), on hydrolysis also yields a thiophenol (4-chlorothiophenol) ; the determination of this by means of 2,6-dibromo-*N*-chloroquinone imine had been reported (6). It was found that 2,5-dichlorothiophenol, and hence phenkapton, could be determined by this method, following the procedure for Trithion almost exactly. For the purpose of comparison, calibration graphs for both acaricides were produced, and in one season (1960) the persistences of the two chemicals on apple foliage were compared.

Kelthane

Two analytical approaches to the colorimetric determination of Kelthane are possible ; these are based on the determination of one or other of the two hydrolysis products, viz. 4,4′-dichlorobenzophenone and chloroform. A method based on the latter has been reported (7) but we preferred to develop the former since we had previously investigated the nitration of Kelthane before and after hydrolysis. Aliquots of a standard solution of the acaricide in carbon tetrachloride, or of plant extracts of unknown content which had been treated with Fullers' earth (Fulmont 700C) to remove interfering substances, were evaporated just to dryness at 40° C by a current of air in 50 ml glass test tubes fitted with B.24 sockets. Hydrolysis was effected by heating under reflux for 30 minutes in a boiling water-bath with N-ethanolic potassium hydroxide. The phenone was extracted with carbon tetrachloride and the Schechter-Haller (8) procedure followed, nitration being carried on for $2\frac{1}{2}$ hours. The colours were read at 515 mμ in a 1 cm cell ; the optical density per 100 μg of 2,2,2-trichloro-1,1-di-(4-chlorophenyl)1-ethanol was 0·750.

Tedion

The method of Fulmer and Cassil (4) was followed almost exactly.

Results

1959 Experiment

In 1959 a single application of each of the new acaricides was made in the Essex orchard where chlorbenside and amiton were used in 1958 (3). All were applied by conventional high-volume spraying equipment and gave adequate commercial control of the mite (1). Details of the concentrations used and of the analytical results obtained are shown in Table I.

TABLE I

PERSISTENCE OF ACARICIDES ON APPLE FOLIAGE, ESSEX, 1959

Treatment (applied on 25.5.59)	Deposit (μg/cm^2) after following intervals of time (days)		
	0	11	35
phenkapton, 0·02%	0·24	0·08	0·03
Tedion, 0·015%	0·35	0·26	0·11
Kelthane 0·034%	1·43	0·91	0·42

1960 Experiment

Essex.—The same three acaricides were applied in Essex in 1960 and at the same concentrations but on a different basis (2). Two applications of each were made ; the analytical results obtained are shown in Table II.

TABLE II

PERSISTENCE OF ACARICIDES ON APPLE FOLIAGE, ESSEX, 1960

Treatment	Deposits (μg/cm^2) after 1st application (23.5.60)				Deposits (μg/cm^2) after 2nd application (16.6.60)			
	0	2	18	24	0	2	12	41
phenkapton 0·02%	0·31	0·22	0·08	0·04	0·31	0·16	—	0·05
Tedion 0·015%	0·49	0·39	0·13	0·07	0·53	0·51	0·31	0·15
Kelthane 0·034%	1·13	0·77	0·30	0·29	1·39	1·09	0·67	0·34

Kent.—The same chemicals were included in a field trial of acaricides which was begun at East Malling in 1960 (2). Two applications of each were made ; analytical results are shown in Table III

TABLE III

PERSISTENCE OF ACARICIDES ON APPLE FOLIAGE, KENT, 1960

Treatment	Deposit (μg/cm^2) after 1st application (23.5.60)					Deposit (μg/cm^2) after 2nd application (31.5.60)				
	0	4	8	15	29	1	3	8	14	29
phenkapton 0·02%	0·32	0·23	0·17	0·02	—	0·42	0·40	—	0·05	Nil
Tedion 0·015%	0·61	0·48	0·40	0·42	0·08	0·91	0·84	0·43	0·28	0·15
Kelthane 0·034%	1·59	1·22	0·83	0·77	0·30	1·50	1·40	0·55	0·55	0·37
Kelthane 0·02%	—	—	—	—	—	1·02	1·21	0·66	0·45	0·33
Kelthane 0·01%	—	—	—	—	—	0·66	0·58	0·34	0·29	0·18

TABLE IV

PERSISTENCE OF PHENKAPTON AND TRITHION ON APPLE FOLIAGE, 1960

Treatment	Deposits (μg/cm^2) at intervals after spraying (14.6.60)					
	0	2	6	17	27	49
phenkapton 0·05% ..	1·22	0·67	0·40	0·13	0·10	0·08
Trithion 0·05%	1·23	0·83	0·33	0·18	0·13	0·03

In addition, in 1960, a field comparison was made of the persistence of phenkapton and Trithion (both at 0·05%). These two chemicals were included in joint studies with the Entomology Section in that year on the codling moth and, in addition to the required analyses of fruits, leaves were collected and analysed (Table IV).

Discussion

The results obtained in the various trials are concordant and the data in Tables I–III show that phenkapton was regularly the least persistent of the three acaricides. Tedion and Kelthane seem to be of the same order of persistence, but a comparison between the three acaricides is made somewhat easier

TABLE V

COMPARISON OF THE PERSISTENCE OF PHENKAPTON, TEDION, AND KELTHANE

Acaricide	Trial	% of initial deposit remaining after following intervals (days)						Approx. half-life (days)
		0	2	4	8	16	32	
phenkapton	Essex, 1959	100	75	59	41	23	12	6
	Essex, 1960	100	64	52	36	20	12	5
	Kent, 1960	100	92	72	48	18	0	7·5
Tedion	Essex, 1959	100	95	90	80	61	38	24
	Essex, 1960	100	90	80	64	44	28	13
	Kent, 1960	100	90	76	64	40	16	13
Kelthane	Essex, 1959	100	90	82	68	52	32	18
	Essex, 1960	100	80	68	54	32	20	10
	Kent, 1960	100	88	76	56	36	24	10

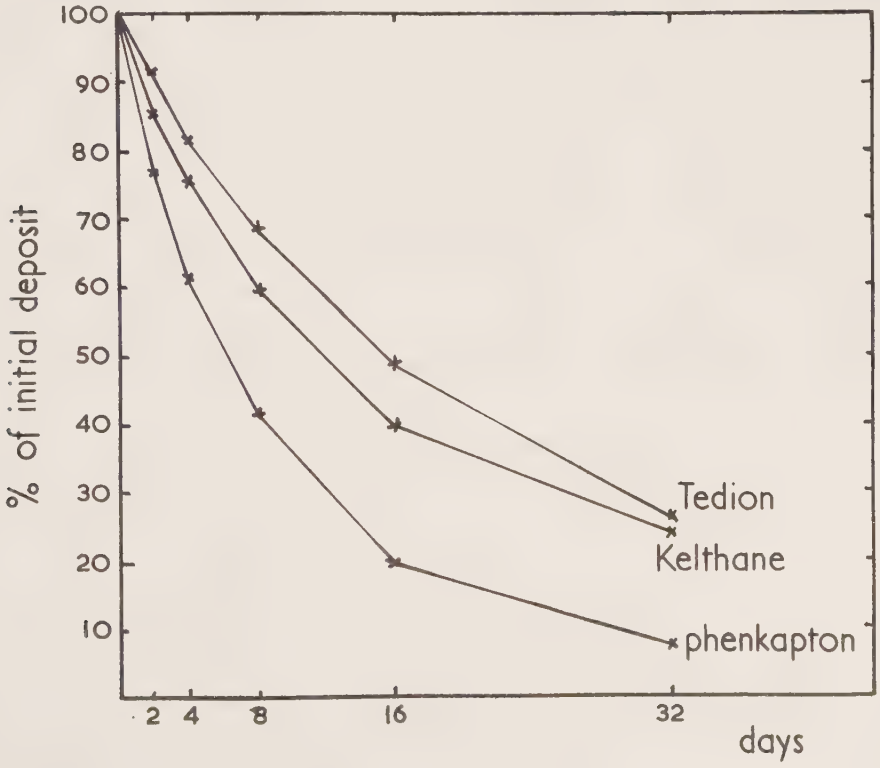

FIG. 1

Persistence of phenkapton, Tedion, and Kelthane on apple foliage

by plotting graphs to show percentage decay against time, and reading off values for the same intervals of time. These data (Table V) and the mean values for each chemical plotted in Figure I, suggest that Tedion may be slightly more persistent than Kelthane. Both of these acaricides appeared to be more persistent in 1959 than at either site in 1960. The figures in Table IV show that phenkapton and Trithion are almost identical in persistence.

It should, of course, be emphasized that these observations on persistence are based solely on an interpretation of data obtained by chemical analysis and do not necessarily reflect the biological performance of deposits present after different intervals of time.

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Samples of analytical grade chemicals were supplied by the Geigy Chemical Company (phenkapton), N. V. Philips-Duphar (Tedion), The Röhm and Haas Company (Kelthane), and The Stauffer Chemical Company (Trithion).

Summary

The deposition in relation to spray concentration, and the subsequent persistence, of three acaricides which are at present effective in controlling the fruit tree red spider mite (*Metatetranychus ulmi*, Koch) have been assessed in field trials on apple by chemical analyses. Phenkapton provided the smallest deposits and was the least persistent. Tedion (based on 2,4,5,4′-tetrachlorodiphenyl sulphone) and Kelthane (based on 2,2,2-trichloro-1,1-di-(4-chlorophenylethanol) were almost equally persistent.

It was also shown that the persistence of the monochloroanalogue of phenkapton, *S*-4–chlorophenylthiomethyl diethyl phosphorothiolothionate (Trithion), was indistinguishable from that of phenkapton.

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Part IV

BULLETINS FOR FRUIT GROWERS

RECOMMENDATIONS FOR CONTROL OF APPLE PESTS

By G. H. L. DICKER

Because of the many chemicals now available it is no longer possible to devise a spray programme in the form of a single chart. In its place this bulletin has been compiled to cover pests of apples. The main emphasis is on time of application, and brief notes on life history are given so that growers can realize why such times are chosen.

Our studies at East Malling have shown that the life histories of all pests occurring up to petal-fall are closely related to stages of bud development. This does not mean that aphids, for instance, hatch at different times on different varieties. They hatch at the same time irrespective of the variety, but on any one variety hatching occurs at the same stage of bud development each year. For reference to life cycles, the varieties Cox and Bramley have been chosen as standards since both are widely grown and the bud stages are synchronized.

This has led us to use bud stages as a guide to time of application, as shown in Fig. 1, since it obviates the need for dates which vary from year to year.

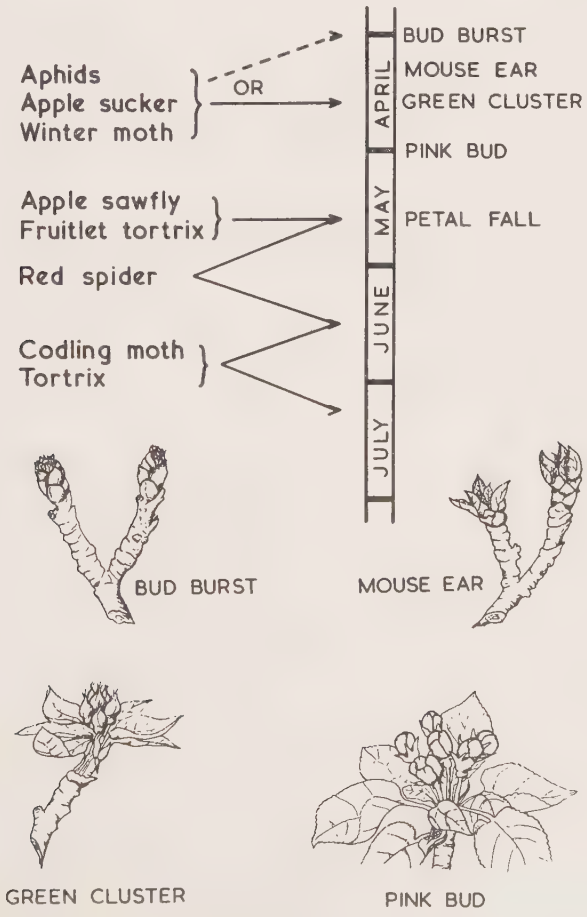

FIG. 1

The recommended timing of sprays against apple pests

On most farms several varieties are grown, and a possible difficulty will arise in deciding which variety should be used as a guide to the timing of sprays. The ideal answer would be to spray when each variety reached the recommended stage. As this is not possible in practice, the programme should be arranged so that the main variety is sprayed at the correct stage of development.

No reference is made to the use of winter washes, since equally effective alternatives are now available which can be combined with routine fungicidal sprays and thus reduce the cost and labour of application. The chemicals mentioned include only those for which adequate information on performance is available and, unless otherwise stated, these can be considered of approximately equal efficiency. Due to variations in the amount of active ingredient which may occur between different brands no reference is made to the dosage rate; this should follow the manufacturers' recommendation, as should all other instructions concerning use.

Work is in progress to coin common names for all chemicals used in pest control ; at present some materials lack a common name whilst others are still little-known to growers. To make the recommendations as clear as possible both common and registered trade names have been included, the materials being listed in alphabetical order.

Aphids

Both the apple-grass aphid, *Rhopalosiphum insertum* (Wlk.), and the rosy apple aphid, *Sappaphis mali* (Ferr.), hatch at the same time. Hatching begins when the buds are breaking, the peak occurs during the bud-burst stage, and it is complete by the time Cox and Bramley have reached the mouse-ear stage.

Control.—As an alternative to winter washing, either DDT or BHC/DDT (emulsion or miscible) can be applied at the bud-burst stage, or an organophosphorus compound can be used at green-cluster.

Results with bud-burst sprays are often unsatisfactory in years of heavy infestations, because aphids have not finished hatching at this time. If, however, spraying takes place at mouse ear when hatching is complete, many aphids will have crept into the opening buds where they are protected from the spray. There is no evidence that aphids will cause any damage if control measures are delayed until green-cluster ; at this stage much more reliable control can be obtained with a phosphorus compound such as demeton-methyl(Metasystox), dimethoate(Rogor), malathion, mevinphos(Phosdrin) or parathion.

The rosy leaf-curling aphid, *Sappaphis devecta* (Wlk.)—the one which causes red and yellow blisters on the leaves—cannot be controlled by winter washes as its eggs are laid under loose bark. On hatching it quickly causes small blisters to form near the edges of young leaves which give protection from contact insecticides such as BHC and DDT.

Satisfactory control is only possible if a phosphorus insecticide is used ; the best time being at green-cluster. This aphid has no migration phase and spreads slowly from tree to tree, so thorough spraying can eradicate it from an orchard and eliminate the need for control in future years.

Apple sucker, *Psylla mali*, Schmid.

The apple sucker is no longer of economic importance in most orchards. It hatches rather later than the aphids, starting at bud-burst and continuing until green-cluster. During this period the young suckers are well protected in crevices in the opening buds.

Control.—The best time to obtain control is at green-cluster, when the fruit buds have opened and the suckers are in exposed positions on the blossom truss. BHC, mevinphos(Phosdrin) and parathion are the most effective materials and one of these should be used against heavy infestations. Adequate control of populations occurring in regularly sprayed orchards can be obtained with the phosphorus compounds recommended against aphids. DDT does not control this species.

Winter moth, *Operophtera brumata* (L.)

Winter moth is usually troublesome only in orchards adjoining woods, from which the young caterpillars drift in on silken threads each spring. The main hatching period is slightly later than for aphids or sucker, from mouse-ear until green-cluster, but hatching is often not complete until pink-bud.

The tortrix caterpillars are also active at this stage but these will be discussed in more detail later.

Control.—Against winter moth the best time to obtain control is at green-cluster ; against tortrix there is probably little to choose between a bud-burst and a green-cluster spray. DDT is both cheap and effective.

Woolly aphid, *Eriosoma lanigerum* (Hsmnn.)

Although it is claimed that galls caused by aphids may form sites for *Gloeosporium* infection on the branches, this species is probably more of a nuisance than a pest on established trees. It tends to occur irregularly and routine control measures are seldom necessary. The main difficulty is to predict when heavy infestations will occur. The widespread attacks in 1961 probably resulted from low mortality due to the very mild winter of 1960/61.

Living aphids occur on the trees throughout the year. The adults gradually die out during late autumn, and young aphids overwinter in sheltered spots such as cankers and under loose bark. These start developing again as soon as the weather warms up in the spring, but it is not until infestations spread to the young wood in June or early July that it becomes important.

Control.—So few experiments have been carried out that our knowledge is based almost entirely on results obtained by growers. One point is quite clear—extremely good cover is necessary if satisfactory control is to be obtained, and a high volume spray is recommended.

The best time to spray is a matter of opinion ; petal-fall is convenient since control of woolly aphid and apple sawfly can then be combined. But this leaves a long period until harvest for the survivors to multiply, and it is probably better to wait until late June or early July and then spray if signs of an impending infestation are visible.

The most effective materials are the phosphorus compounds such as azinphos-methyl(Gusathion), demeton-methyl(Metasystox), dimethoate(Rogor), malathion, parathion and phosphamidon(Dimecron). BHC is also quite good and can be used at petal-fall, but later applications should be avoided until evidence is obtained that it has no effect on flavour.

Fruitlet mining tortrix, *Pammene rhediella* (Clerck)

The normal host of this moth is hawthorn and it has spread to apple from this source. Moths are on the wing during the blossom period and for a short while afterwards. Eggs are laid mainly on the undersides of the rosette leaves. As soon as the caterpillars hatch they seek shelter at the centre of a fruit cluster, or else enter the eye of single fruits or attach a leaf to a fruit. Once in these positions they quickly protect themselves with silken webbing, so control measures should be applied before hatching begins.

Control.—Our knowledge is based on the results obtained by growers and other workers. This species seems to be very easily controlled by DDT at petal-fall and there are indications that it can even be eradicated, thus eliminating the need for repeated annual applications. Where hawthorn hedges are present these should also be treated to remove a source of reinfestation.

Apple sawfly, *Hoplocampa testudinea* (Klug)

Eggs are laid only whilst blossom is present, and hatching starts during the week following 80% petal-fall. This pest mainly attacks dessert varieties ; with the exception of Edward VII it is seldom of economic importance on culinary varieties.

Control.—The best time to spray is during the week following 80% petal fall. If spraying is later than this some larvae will have started tunnelling under the skin of the fruitlets. Although these may be killed the fruit will be blemished due to the presence of ribbon scars.

BHC and parathion are the most effective materials, but satisfactory control of average infestations can be obtained with demeton-methyl(Metasystox) and dimethoate(Rogor), which will also give control of the early hatched red spider mites. Nicotine gives moderate but less consistent results.

Fruit tree red spider mite, *Metatetranychus ulmi* (Koch)

The normal hatching period starts at pink-bud, about half the eggs have hatched by petal-fall, and the remainder hatch during the following 3–4 weeks. In occasional orchards the hatching period may be as much as four weeks later than this, so careful observation is necessary to make sure hatch is in progress before any sprays are applied. By the beginning of June, summer eggs are more numerous than mites ; these start hatching during the first half of June, but for the rest of the season eggs and mites occur in approximately equal proportions.

Control. –If winter egg populations are high the first spray should be applied at petal-fall to prevent leaf injury whilst fruit set is in progress. When winter eggs are few, spraying can be delayed until early June. Past experience has shown that two applications are usually necessary to obtain good control throughout the season, with an interval of about three weeks separating the sprays.

In many areas resistance has already occurred to chlorbenside and chlorfenson and, in isolated

cases, to the phosphorus compounds, so this factor will influence the choice of chemicals. Another point to be considered is the stages in the life history of the mite against which various chemicals are toxic, for example :

(*a*) chlorbenside, chlorfenson, fenson (PCPBS) and Tedion are effective against summer eggs and very young mites,
(*b*) azinphos-methyl(Gusathion), demeton-methyl(Metasystox), dimethoate(Rogor) and phosphamidon(Dimecron) kill active mites of all ages but not eggs,
(*c*) ethion(Embathion), Kelthane and phenkapton kill both active mites and summer eggs.

From the point of view of efficiency there is probably little to choose between these materials. When control measures are delayed until June, there should be some benefit from using a chemical toxic to summer eggs since these are more numerous than mites at this period.

One of the main worries is the development of resistance. It is possible that this can be delayed if materials of quite different chemical structure are alternated. Current opinion favours a biennial alternation, that is to use one material for two consecutive years, then change to another for the following two years. In this way the surviving mites are given a longer period in which to interbreed and so reduce the proportion of highly resistant specimens.

For this purpose the chemicals listed above can be regrouped into four classes :

(i) Chlorbenside, chlorfenson and fenson,
(ii) Tedion,
(iii) The organophosphorus compounds, i.e. all those grouped under (*b*) and (*c*) above, except Kelthane.
(iv) Kelthane.

If alternation is practised, more care is needed in devising the post-blossom spray programme as, in years when group (iii) is not being used against red spider, these materials must not be used against sawfly, codling or tortrix. This does not present any great difficulty as, on these occasions, BHC can be used against sawfly and either DDT, Rhothane or Sevin against codling and tortrix. Kelthane has caused severe russeting to Cox when applied up to two weeks after petal-fall, but no injury has occurred from later applications.

Codling moth, *Cydia pomonella* (L.)

The date of emergence of moths is not as predictable as for the previous species, nor are there any well defined stages of growth after petal-fall to which it can be related. In the average season, moths are present from early June until the end of July, but exceptionally warm weather in late May will sometimes necessitate earlier sprays than recommended in this bulletin. Eggs start hatching about mid-June and, if allowed to survive, some of the caterpillars hatching during June will develop into second generation moths in August. These will lay eggs which result in ' late ' attacks in September.

Control.—The aim should be to destroy the early hatching caterpillars, and so eliminate the risk of a partial second generation, as well as protecting fruit against entry until the end of July. This can be done by applying the first spray by mid-June and following with another three weeks later, or two more at fortnightly intervals, depending on the persistence of the chemical in use.

The most persistent chemicals are azinphos-methyl(Gusathion), DDT, phosphamidon(Dimecron), Sevin, and Rhothane, although the last named is not quite as effective as the others. Malathion is less persistent and would need to be applied at fortnightly intervals. Lead arsenate gives only moderate control but is the only chemical which can be used against codling moth without destroying predators of the red spider mite ; its performance can be improved if an additional spray is applied high volume at petal-fall.

Fruit tree tortrix moth, *Archips podana* (Scop.)

Young caterpillars start emerging from overwintering cocoons when the buds are bursting and, from the little information available, emergence seems to continue until green-cluster. The earlier ones burrow into the fruit buds where they are protected against sprays until the buds are fully open at green-cluster. After this period caterpillars live in webbed leaves.

Moths are on the wing from mid-June until early August and again in September and October. It is probable that larvae arising from the first generation of moths are responsible for injury to the maturing fruits in September and October.

Control.—Unless damage occurs to fruits in early autumn it is doubtful whether this tortrix can be considered a pest of economic importance. No doubt there are some farms where a pre-blossom

spray of DDT gives adequate control throughout the season, and probably many more where, as has been found at East Malling in recent years, even the omission of this spray will not lead to any fruit damage. So, unless other kinds of caterpillars are troublesome in spring, it may be worth omitting a pre-blossom DDT, on a small area at first, to see whether this spray is really necessary.

Where damage occurs to maturing fruit, control measures should be directed against the summer generation, and these can be combined with control of codling moth. The normal programme against the latter pest, of a spray in mid-June and another three weeks later, has also given excellent control of tortrix. The most effective chemicals are azinphos-methyl(Gusathion), Rhothane and Sevin ; DDT is not quite as good, and lead arsenate is unsatisfactory.

It will be noted that the chemicals differ slightly in their order of efficiency towards codling and tortrix. Gusathion and Sevin are equally effective against both pests ; DDT is more effective against codling than tortrix ; whilst Rhothane appears to be more effective against tortrix than codling. The choice will therefore depend on which is the more important pest.

Summer fruit tortrix moth, *Adoxophyes orana* (F.R.)

This species has a life cycle which is very similar to the previous one except that the flight period of first generation moths is slightly earlier. Damage is caused by the maturing caterpillars which arise from this generation of moths and it usually occurs in late July or August.

Control.—There is very little information about control in England, but it is almost certain that the recommendations made against the fruit tree tortrix will be equally effective against this species.

Acknowledgement

My thanks are due to Miss Rosemary Dolling who drew the bud stages illustrated in Fig. 1.

Summary

Brief notes on life history and control measures are given for twelve species which occur on apple.

CONTROLLING APPLE MILDEW

By M. H. MOORE and R. T. BURCHILL

The disease

Apple mildew is caused by *Podosphaera leucotricha*, one of the powdery mildew fungi. The disease is difficult to control chiefly because it overwinters inside the buds and is therefore already present on the tree in an active form when the growing season starts at bud-burst. Moreover, as the fungus produces vast numbers of spores, it can spread rapidly on new foliage in spring and summer.

The familiar white leaf-trusses seen in early spring result from the growth of buds infected in the previous growing season. Before the buds burst the closely-packed leaf rudiments are already covered with the fungus and bearing chains of spores, which later give the trusses their characteristic glistening appearance. The spores are wind-borne to fresh leaves and there set up new infections. Infection is possible over a wide range of temperatures, but the most favourable conditions are temperatures of 60° to 75° F and fairly high humidity without rain. Young tip leaves are more susceptible than older ones, and as they are readily infected while still partly furled, many new infections arise on the hairy undersides. As the leaves expand and flatten the upper surfaces also become mildewed, and the buds are infected chiefly by growth of the fungus down the leaf-stalks. Growing tips carry mildew with them, and so whole shoots remain infected throughout the season. Severe infection eventually stunts the trees and greatly impairs the crop.

Control

The main problem of control lies in finding a satisfactory way of preventing mildew infection of new foliage, thereby indirectly protecting the buds in the leaf-axils so that they overwinter mildew-free. Where summer or autumn inspection shows that mildew is already severe, however, it is advisable first to consider ways and means of reducing the mildew load for the following season. There are three lines of attack :

(1) Cutting-out in winter and spring ;
(2) spraying with DNOC/petroleum to reduce the level of mildew arising from diseased buds ;
(3) spraying with lime-sulphur and wetter to scorch the white trusses at pink-bud.

Growers should choose which of these operations is likely to be the best proposition for their orchard conditions, as it would be folly to suppose that every one of these measures is economically applicable in every case. *But whatever is done at this stage must be followed by a close schedule of protective sprays* (pp. 123-4) *from blossom time until at least the end of June if the disease is to be really mastered.* Half-measures merely put off the problem for another year.

1. Cutting-out in winter and spring

Suitable for small or medium trees, this operation should be combined with winter pruning but not left there, for winter pruning alone cannot account for every infected bud ; indeed, it is not possible to detect some of them in the dormant state, for not all have pointed, ragged scales that can easily be seen. Mildewed shoots are silver and fairly obvious. At least one further round should be made between green-cluster and pink-bud to snip off the white trusses before the flowers open and make the job more difficult. Growers who have severely-infected plantations should consider the advisability of tipping all apparently healthy extension shoots by removing the top inch or so in winter pruning to save time later at a busy period. The local advisory officer should be consulted as to the desirability of this emergency measure in the prevailing circumstances.

2. Spraying with DNOC/petroleum

An account of the experiments on which this line of attack is based will be found elsewhere in this Annual Report. Briefly, it has been shown that a DNOC/petroleum-oil emulsion spray of 0·1% DNOC and 3% petroleum oil, applied in winter or at bud-swelling, will appreciably reduce the overwintering source of infection in the buds. Many new leaves and shoots are thus given a chance to grow away from the disease when they are released from infected buds.

The spray is costly and at best will not provide an entirely clean start to the season as careful cutting-out might, and it should be regarded as a possible alternative where cutting-out is impracticable. Use of this spray *alone* does not, however, provide a simple way out of a difficult situation.

3. Spraying to scorch the mildewed trusses

This spraying, preferably at pink-bud, should be regarded mainly as part of a preliminary eradication programme and not as the beginning of protective spraying, though it does provide limited protection, especially in some seasons. Probably the best spray to use is 1½-2% lime-sulphur with a wetter to ensure that the waxy mildew trusses do not escape through not being well wetted. The mild sulphurs and dinocap* are less effective for this purpose.

Spraying under cold, windy conditions should be avoided if possible on account of the risk of scorching healthy leaves. This risk should be set against the severity of the mildew, especially on Cox's Orange Pippin. Where thorough cutting-out has been possible, this eradicant spray should not be necessary, but it might well be used in support of earlier DNOC/petroleum spraying. Good results have been obtained from lime-sulphur at high concentration applied as small droplets ; complete wetting of the mildewed tissues is of course impossible, but the small spots of strong spray cause the mildew to collapse.

Protective spraying in bloom and post-blossom

Several spring and summer sprayings are essential to protect the now mildew-freed trees from fresh foliage- and bud-infection ; neglect of this precaution can be disastrous, for the outbreak is soon re-established by wind-borne spores from other orchards. As the youngest leaves are the most susceptible, the greatest risk coincides with the period of most rapid growth. Both tree-growth and mildew flourish best when the weather is warm enough; both are retarded in cool weather, and a successful sequence of sprayings can be designed on this basis.

The objective at this period is quite different from that at pink-bud in that new leaves should be protected as they are produced. The six weeks or so following full bloom should be looked upon as the most critical period of all for preventing a mildew epidemic, for then in most seasons all the environmental factors strongly favour a heavy attack. *Failure to prevent early establishment of new mildew at this time has probably been a greater cause of the recent severity of mildew than any other single factor.* Unfortunately, it is difficult to detect early mildew because new infections are often mixed up with the hairs on the undersides of young leaves ; otherwise the grower might be warned of impending trouble as with the first scab spots.

It is better to apply sprays at even weekly intervals during this critical stage than to keep to a rigid 14-day schedule throughout the season, though the 7-day interval is less important in spells of cool weather. Later, when the growth rate slackens, the interval can be increased. Sulphur sprays or dinocap give good protection against the early stages of an epidemic, but it is most important that the growing tips should be well covered. Where apparently faultless spray schedules sometimes fail, the reason probably lies here. Slow travel through the plantation is better than an attempt to apply the same volume at speed.

If these suggestions are carefully followed, growers who have hitherto found it difficult to decide how far into the summer to continue spraying may be agreeably surprised that the problem is no longer acute, for the usual epidemic at this stage has already been prevented. Unless sprays must be applied against gloeosporium most growers rightly hesitate to risk possible mechanical damage from late-season spraying amongst heavily-laden trees, and though some tip infections are inevitable, they are probably best left for winter and spring pruning. It is, of course, good practice to remove any within reach during a fruit-inspection walk at any time ; the shoots should be cut well below the obvious mildew.

Summary of recommendations

The measures of control discussed above may be conveniently grouped around five main periods (A-E, below) from winter to the following summer.

A. *Winter.*—Cut out all mildew seen in winter pruning, and, where desirable, tip all extension shoots. If trees are too large to prune in this way, spray in December or January with DNOC/petroleum at 0·1% DNOC and 3% petroleum oil avoiding windy, quick-drying conditions, which may lead to slight oil damage.

B. *Bud-swelling to burst.*—If the winter DNOC/petroleum spray was omitted, there is still time to apply it where desirable.

C. *Green-cluster to pink-bud.*—Cut out white trusses where possible and burn them or, if preferred, drop them to the ground where they will soon wither. Where complete cutting-out is not possible, spray

* Dinocap is the recommended common name for the active chemical in the commercial preparations Karathane and Crotothane.

with 1½-2% lime-sulphur with a good wetter added to dry up any mildew remaining, but preferably avoid cold, windy conditions ; there is little or no risk of fresh mildew infection in these circumstances. Where preferred, lime-sulphur concentrate can be used as a small-volume spray ; at either volume no additional chemical is necessary for scab.

D. *In blossom.*—Spray with one of the following :

1. Colloidal or dispersible sulphur at rates approximately equivalent in sulphur content to three quarts of lime-sulphur (about 2 lb sulphur) per 100 gallons ;
2. a mixture of one of these ' mild ' sulphurs at half strength with 3 *pints* of lime-sulphur per 100 gallons, and a half-quantity of added wetter except when used with other wetting sprays.
3. 3 quarts of lime-sulphur per 100 gallons with a full quantity of added wetter except as above (2).
4. dinocap at ½ lb of 25% wettable powder per 100 gallons, with a half-quantity of added wetter except as above (2). Growers may prefer dinocap for Cox's.

Wait until the early petals are falling if pollination conditions have not been good, and see that growing tips are well wetted.

E. *After blossom.*—Again choose one of the above sprays* and apply it at weekly intervals if the weather is warm and therefore most suitable for mildew ; the interval can be increased to 10 days in cool weather and the strengths of the fungicides increased by one-quarter (e.g. 1 gallon of lime-sulphur instead of 3 quarts ; ¾ lb dinocap instead of ½ lb, and so on). Keep up a thorough programme without fail till about the end of June. If by then the disease is well under control, as it should be, the need for further spraying will be governed by the circumstances. Much depends upon the weather and growth conditions and the risk of mildew spores from surrounding areas.

Measures grouped under A-C do not apply to clean trees, but D and E are very important for preventing infection on all trees of susceptible varieties ; indeed, really thorough and close attention to D and E could preclude the need for A-C even on trees already heavily infected. Nevertheless, spraying in bloom and afterwards has a less exacting task where A-C have provided a good beginning.

Note on combined scab and mildew control

Where sulphur has been used at frequent intervals, scab also should be well controlled, but an additional fungicide would be necessary for scab where dinocap is used against mildew. Among the available scab fungicides, mercury, thiram, ziram, and dodine† preparations vary in their limited effect on mildew, and captan gives no control ; none of these alone is likely to prevent a mildew epidemic under favourable conditions, though some may contribute towards its delay.

Note on low-volume spraying

A thorough wetting spray is advisable wherever trees are already freely mildewed, i.e. mildew trusses or fresh spots on young foliage must be well wetted if they are to be dried up. The only reliable exception is lime-sulphur concentrate, and even this spray must provide good, uniform cover in small droplets for successful eradication.

A close sequence of low-volume sprays can, however, give good control by protective action during the critical May-June period provided that they give good cover and that the trees are virtually mildew-free at the outset. The main difficulty with low-volume spraying against apple mildew is failure to provide good enough cover of the hairy undersides of young tip leaves.

Summary

The apple powdery mildew problem is divided into two parts : eradication of overwintering bud-infections, and protection of healthy leaves and buds. The relative merits of cutting-out and of spraying to achieve differing objectives are reviewed, and a chronological summary of recommendations is presented, with a note on low-volume spraying.

* It is stated by certain growers in dry areas that post-blossom sulphur/dinocap, without pre-blossom lime-sulphur, is giving very good control of mildew on Cox's.

† Dodine acetate is the recommended common name for the active chemical in the commercial preparation Melprex (Cyprex).

THE MOTHER TREE SCHEME

By A. F. POSNETTE

Research during the past decade has shown the presence of many viruses in fruit trees and the effect they have in reducing growth and cropping. Several fruit abnormalities have proved to be bud-sports perpetuated in scions, and many instances of the wrong variety being supplied from nurseries have also been reported.

The Mother Tree Scheme was adopted to enable nurserymen to reduce these risks. It aims to provide propagators with the best scion-wood of commercial varieties available at the Research Station. As improved material becomes available, either through the selection of better cropping and higher quality strains or by the elimination of latent virus infection, it will be issued to replace the clone in current use.

The trees from which Mother Trees are propagated were usually selected from experimental plots on which individual tree yields have been recorded for many years. Great care was taken to ensure that the source tree was producing good quality fruit typical of the variety. Occasionally source trees were selected from commercial orchards and propagated on the Research Station for careful observation before distribution in the scheme. The only varieties distributed without these checks at East Malling are those recently produced by the John Innes Institute and first issued through our Mother Tree Scheme.

The Mother Trees are described as virus-tested rather than virus-free because it is not possible to ensure that no viruses are present. Tests can be done only for known viruses, and newly discovered viruses require new tests. Furthermore some commercially valuable varieties seem to be totally infected and it is preferable to distribute the least-infected material rather than to force nurserymen to use unselected, probably inferior, scionwood.

The virus diseases and latent infections known to occur in Britain

Apple

Chat fruit
*Chlorotic leaf spot
†Epinasty
Flat limb
Mosaic
Rubbery wood
Star crack
‡Stem pitting

Pear/Quince

Bark necrosis
Blister canker
Mosaic
Sooty ring spot
Stony pit
Stunt
Vein yellows
Yellow blotch

Cherry

Green mottle
Leaf roll
Line pattern
Little cherry
Necrotic ring spot
Necrotic rusty mottle
Prune dwarf
Rasp leaf
§Ring mottle
Rugose mosaic
||Rusty mottle
Sour cherry yellows

Plum

Bark split
Green mottle
Line pattern
Necrotic ring spot
Plum pox
Prune dwarf

* All apple varieties infected.
† All apple varieties except Merton Worcester infected.
‡ Many apple varieties infected.
§ Noir de Guben and B. de Schrecken entirely infected.
|| Roundel entirely infected.

SCION VARIETIES OF WHICH MOTHER TREES ARE NOW AVAILABLE

Apple

All of the apple Mother Trees are free from rubbery wood and mosaic. Tests for chat fruit, flat limb, star crack and stem pitting viruses are not yet complete, but Lord Lambourne M.139 is known to be free from chat fruit.

Beauty of Bath	M.150	Laxton's Epicure	M.149
Bramley's Seedling	M.127	Laxton's Fortune	M.125
Cox's Orange Pippin	M.124	Laxton's Superb	M.122
Early Victoria	M.147	Lord Lambourne	M.139
Egremont Russet	M.152	Merton Beauty	M.132
Ellison's Orange	M.151	Merton Worcester	M.141
Grenadier	M.148	Sunset	M.137
Howgate Wonder	M.130	Tydeman's Early Worcester	M.129
James Grieve	M.138	Tydeman's Late Orange	M.121
Jonathan	M.128	Wagener	M.131
Lane's Prince Albert	M.145	Worcester Pearmain	M.126
Laxton's Advance	M.146		

Pear

The Beurré Hardy Mother Trees (and trees double-grafted with Beurré Hardy) are infected with a mild strain of bark necrosis virus which is latent in pear. Tests for latent stony pit virus are still in progress.

Beurré Hardy	M.201	Williams' Bon Chrétien	M.205
Conference	M.202	Merton Pride	M.206
Doyenné du Comice	M.204		

Cherry

All virus tests except those for little cherry have been completed.

Amber (Kent Bigarreau)	M.508	Merton Bounty	M.505
Bigarreau Gaucher	M.509	Merton Favourite	M.510
Bigarreau de Schrecken	M.517	Merton Glory	M.506
Bradbourne Black	M.512	Merton Heart	M.503
Early Rivers	M.501	Merton Premier	M.513
Florence	M.518	Merton Reward	M.520
Frogmore Early	M.515	Montmorency	M.519
Géante d'Hedelfingen	M.507	Napoleon	M.502
Governor Wood	M.514	Noir de Guben	M.511
Merton Bigarreau	M.504	Roundel	M.521

Plum

All virus tests have been completed.

Cambridge Gage	M.301	Pershore Yellow Egg	M.305
Czar	M.311	Prune Damson	M.313
Early Laxton	M.303	Purple Pershore	M.306
Marjorie's Seedling	M.309	Severn Cross	M.304
Oullins Golden Gage	M.308	Warwickshire Drooper	M.310

ROOTSTOCKS

Some rootstock clones appear to be entirely infected with certain viruses, perhaps because the clone was originally propagated from root-suckers of a grafted tree. Other clones consist of infected and non-infected plants, while a few clones seem to have entirely escaped infection, at least in the representatives on the Research Station. Some recently discovered apple viruses, such as chlorotic leaf spot, epinasty and stem pitting, which *apparently* do not cause disease symptoms in commercial varieties, have been found in all plants tested of the Malling rootstocks except M.XII, M.XVI, M.26 and Crab C. Of the MM stocks, MM.109 was entirely infected ; no infected plants were found in MM.104 and MM.111, but some MM.106 were infected and some were not. MM.104 and MM.111 are now used as rootstocks for apple Mother Trees. There is, however, no advantage in having one

component (the rootstock) free from these viruses if they are present in the other component (the scion clone).

The rootstocks M.II., M.IV, M.VII, M.IX and M.XVI have been virus-tested, and selected clones free from mosaic, rubbery wood and chat fruit viruses are being propagated. Clones of the other Malling rootstocks and of the Malling-Merton series have been selected that are free from mosaic and rubbery wood, but the protracted tests for chat fruit virus are not yet completed ; tests for the other viruses known to infect apple are also in progress. Due to the time needed to propagate large quantities of stocks from a single plant, only one of these re-selected apple clones, M.VIIa, is available in sufficient numbers for distribution to nurserymen.

Virus-tested clones, apparently free from all viruses, of Quince A and Mazzard F.12/1 were recently made available to nurserymen.

HOW TO MAKE THE BEST USE OF AVAILABLE MATERIAL

Mother Trees should be planted in an isolated plot, and not close to untested trees from which virus may spread by natural root grafting or by other means : this is particularly important with cherries and plums in which spread occurs more rapidly than among pome fruit trees.

Care should be taken to see that stock-scion unions are clearly marked so that stock shoots cannot be used inadvertently as scionwood. This is most likely to happen with cherry varieties high-worked on F.12/1.

Whenever possible scionwood should be taken directly from the original Mother Trees distributed from the Research Station, rather than from their progeny. Scions from Mother Trees should *on no account* ever be top-grafted or framework-grafted on other trees for the rapid multiplication of scionwood.

Nurserymen's Mother Trees will be virus-tested periodically to find out how long they remain uninfected and whether or when they should be replaced. Tests were begun in 1960 on all the surviving cherry Mother Trees that were distributed between 1953 and 1955.

Summary

The methods used in the selection of Mother Trees are described, and the varieties of virus-tested scions and rootstocks available for distribution are listed.

FRUIT GROWING AND FROST PROTECTION IN FRANCE AND THE RHINELAND

By IRENA MODLIBOWSKA, J. MacCORMICK and C. H. W. SLATER

During the last fifteen years spring frosts have been more frequent and severe in France and Germany than in England, causing great losses to fruit growers. In both these countries fundamental research and trials of various methods of frost protection are being made. March and May frosts in 1961 offered a good opportunity of seeing and discussing the results of practical frost protection when the main regions of dessert apple, pear, and peach production in France and vineyards along the Rhine in Germany were visited by the writers during June (Fig. 1).

France is a very important producer of fruit. She stands second among the countries of Europe for peach production, third for plum and for cherry, and fourth for apple and for pear production. Although apples are grown throughout the country, dessert apples are produced mainly in the Loire Valley, the South West, the Rhône Valley, Provence and Auvergne.

Fruit growing

Apples.—For France as a whole the main commercial apple varieties are Reinette du Canada, Belle de Boskoop, Reine des Reinettes and the American varieties, Golden Delicious and red sports of Delicious, Richared, Starking and Shotwell. The American varieties are especially characteristic of recent large-scale plantings.

Old orchards mostly on seedling roots are widely planted, at 18 to 37 ft square. The newer orchards planted since the war are for the most part intensive cultures on M.IX, M.VII, M.II, and M.IV planted 6 to 9 ft apart in rows 12 ft apart. This seems too close for the more vigorous stocks M.II and M.IV. Some orchards are being planted on MM.104 and MM.106.

Intensive cultures are laid out as *haies fruitières* (fruiting hedges), palmettes or goblets, and occasionally as bush trees. Clean cultivation prevails and is only occasionally replaced by a grass sward, either natural or mixed with white clover. Swards are, however, much more characteristic of the extensive orchards on calcareous soils in the south, which are often situated along the rivers and are therefore subject to flooding.

Pears.—Provence, the Rhône Valley, the Loire Valley and the Paris region grow most of the pears. Two varieties make up 50% of the production, namely Williams' Bon Chrétien and Dr. Jules Guyot. The latter is picked green, ripened artificially and put on the market in July before Williams'. It has become very popular with growers in the last decade. The August glut of Williams' has created the present trend to plant Passe Crassane, a dessert variety which will keep until the spring.

Three types (not clones) of quince account for 90% of the rootstocks used for pears. The oldest, the reputedly frost resistant Quince de Fontenay, is best suited to the Paris region. The Angers quince, though easily propagated, commonly shows incompatibility and moreover is unsuited for the south, where it is replaced by the more vigorous Quince de Provence. The latter was said to be relatively lime and drought tolerant and to have good compatibility with pears, which are usually grafted directly onto it.

Pears are trained usually as U-forms, palmettes or as *haies fruitières* and are kept in clean cultivation, planting distances being 6×9 or 9×9 ft.

Peaches.—Peach growing is largely confined to the south and is specially developed in the lower Rhône Valley. Amsden ripening in the first week in July, is the commonest variety (25–30%), but early varieties, such as Mayflower, Robin and Morettini 1, are able to command high prices and are of great importance. During full season there is a glut of peaches on the market and prices are very low. White-fleshed peaches are preferred by the consumer but the yellow-fleshed varieties e.g. Dixired and Redhaven, which are easier to grow, handle, and transport, are favoured by the growers.

One of the most important problems in peach growing is that of rootstocks. A rootstock is sought which combines resistance to asphyxiation and drought, tolerance of calcareous soils, compatibility with most varieties, and ease of propagation. No rootstock in use at present approaches this ideal. Peach seedlings are most commonly used in favourable conditions in the south, almonds on calcareous soils and Black Damas on soils liable to waterlogging. A selection of St. Julien d'Orléans is promising.

Peaches are grown mainly as bush trees or goblets at a spacing of 18 or 22 ft square and kept under clean cultivation.

Apricots.—From the Roussillon area in the south-east come more than half of France's apricots, the main variety being Red Roussillon. The remainder, among which Luizet is the dominant variety, come from the lower Rhône Valley and Provence. The gage Reine Claude and peach seedlings are commonly employed as rootstocks in the Roussillon region. Apricot seedlings from North Africa (*Mechmech*) and almond, especially for the variety Luizet, are also used.

FIG. 1

Fruit growing regions in France. . . . Route of the research tour

Plums.—The chief region of plum cultivation is in the east (45%). Mirabelle is the leading variety but Quetsches and various gages are also grown. A further 25%, mainly for drying, is grown in the south-west. Of local varieties, the Prune d'Ente and its selection P707 are best for drying.

Other commonly grown varieties are Oullins Golden Gage, Reine Claude Dorée, Reine Claude de Bavay and Royale, and the Japanese plums : Golden Japon—a yellow variety, Florenzia and Methley—red varieties. St. Julien, Myrobalan and Black Damas are the most important rootstocks. Marianna is used for Japanese plums.

Strawberries.—Strawberries are the most important small fruit crop with the largest production (25%) in the east. There, in the Moselle area, Mme. Moutot is mostly grown, which in spite of poor flavour is the main French variety (60%). Second among regions of strawberry cultivation stands Vaucluse (16%), where Ladette, early, with small orange-red fruits is the main variety. Surprise des Halles, more upright with brighter coloured fruits which transport better, is rapidly ousting the older variety Surprise de Vaucluse. Other varieties are Gautheir (Voltaire) late, very fertile, although

the fruits are often deformed (fasciated), and Senga Sengana, a heavy cropper, important for the canning industry. There is a strong tendency to grow strawberries for only one to two years, planting them in August and gathering the first crop the following April, thus minimizing the effects of virus infection.

Research

Most of the research in agriculture, both practical and fundamental, is conducted at the Institut National de la Recherche Agronomique (INRA) founded in 1946. It comprises 14 central stations grouped together at Versailles but working independently on various aspects of agriculture, each having their regional stations in various parts of the country.

At the Central Station of Agricultural Bioclimatology at Versailles the main problems investigated are ecology of cultivated plants (wheat and vine), plant and soil water relationships, and climatology. The latter includes analysis of the frequency of frosts, studies of microclimate methods of frost protection and the measurement of critical temperatures for fruit trees at various stages of their floral development.

Apart from INRA at Versailles we also visited the two main fruit research stations at Angers and at Pont-de-la-Maye, near Bordeaux.

The *Angers* station is concerned mainly with improvements in apple and pear production. At present its main work is on testing and selection of rootstocks, particularly quinces from the point of view of their ease of propagation, tolerance of calcareous soils, and compatibility. Experiments with apple rootstocks, including Malling selections, are also in progress.

At *Pont-de-la-Maye* stone fruits are the major concern, especially the breeding and selection of new, improved varieties of peaches, prunes, and plums, including Japanese plums. There is an extensive programme of breeding and selection of rootstocks for ease of propagation, compatibility, tolerance of calcareous soils, and resistance to asphyxiation, to bacterial canker, and to nematodes. Various clones have already been selected and are undergoing extensive trials e.g. Brompton P20, Myrobalan P34, Agen Plum P43, Marianna P81, and Almond P61.

Among other problems under investigation are the chilling requirements of the peach and its relation to bud drop, an important problem in Tunisia. Gibberellic acid was found to help in breaking the rest period in cuttings.

At *Montfavet* near Avignon we visited a new station for market garden plants, mainly strawberries, tomatoes, artichokes and melons. It houses the national collection of strawberry varieties and is engaged in breeding for precocity, resistance to damage during transport and to botrytis. Experiments are also being made to establish the best time for planting strawberries.

In the same region near *Nîmes* is the Compagnie Nationale d'Aménagement de la Région du Bas Rhône et du Languedoc, which by constructing canals and water towers will irrigate large areas in this region with lime-free water from the Rhône. At present 30,000 acres are irrigated, and by the end of next year this will have risen to 80,000 acres. When the scheme is completed it will comprise in all 200,000 acres. The use of piping and sprinklers is encouraged by a scheme whereby this equipment can be borrowed from the company.

There also exists a *private research* station, that of Mr. F. Robin at Vernou-en-Sologne, who grows fruit profitably on a light sandy soil (2 ft deep with an underlying layer of clay) with the help of sprinklers used for both frost protection and irrigation. He also uses heaters for frost protection in some of his orchards. His main work is on testing fungicides and insecticides and on conducting manurial experiments, including the control of magnesium and boron deficiencies.

There are other progressive growers, who, ever ready to take up new ideas, assist in their testing on a large scale and their subsequent popularization. We visited for example Mr. L. Rollin at Bazainville, where a colloquium has been held on frost protection by sprinkling and recently also on the use of hydraulic equipment in fruit plantations. He has shown that with irrigation and frost protection by sprinkling, fruit growing on the deep Fountainebleau sands can be made more profitable.

Frost protection

Dangerous spring frosts occur in France every 3–5 years with very severe ones every 5–12 years, entailing an average loss of 10 million NF annually. Frost protection in fruit plantations is therefore very important, and heating and sprinkling with water (Fig. 2) are used as the only practical methods of protection against severe frosts.

Heating

Heating with *oil heaters* is well established in both France and Germany despite the expense and troublesome nature of the practice. In France the open, small Gelivore heaters are the most popular.

Frost protection by sprinkling of a 37 acre orchard of Mr. L. Rollin at Bazainville, France (*Courtesy* Mr. [illegible]

[*face page 130*

FIG. 3

The commonly used Gelivore heater beside a locally made stack heater. In the background stacked Gelivore heaters full of oil

FIG. 4

Rotary sprinkler on tripod for frost protection in a peach orchard

FIG. 5

Freezing indicator among strawberry plants

FIG. 6

Minimum, maximum, and alarm thermometers and a permanent sprinkler installation in pear orchards of Mr. Lemesle in France

They are cheap, easily lit, easy to handle, stable, stack well in store, and give a more uniform heating in the orchard than the large heaters. They hold from 1 to 3 gal. and, according to size, 60–120 are needed per acre. They are, however, inefficient in emission of radiant heat, produce much smoke and require a great deal of labour for distribution, lighting, cleaning and refuelling. Larger heaters of the Californian return stack type have a better combustion and thus produce less smoke and more radiant heat but they require much more storage space. They are often used at the edges of protected areas, where more heat is needed.

Small oil heaters are used also in Germany but of improved design, the simplest having deflection covers, the more complex having stacks, which preheat the incoming air for better combustion, and devices that automatically regulate the air supply. These heaters produce less smoke and emit more radiant heat than the French ones. On dismantling, corresponding parts can be stacked compactly. At Trier tests are carried out by Dr. Aichele on the various heaters being manufactured. In order to pass this test the heaters must emit at least 30% of the heat as radiant heat, while smoke production must be low.

To reduce the labour requirements of oil heaters the *Brenntag Anlage* system was developed. In this system oil is pumped from a central supply through pipes to burners installed in the orchards. The amount of heat produced can be centrally regulated by altering the oil pressure, but each burner must be lit individually. This system is very expensive to install and we did not see any plantation equipped with it.

Briquette heaters are still used in some vineyards. They emit more radiant heat near the ground than oil heaters but require more labour (2 men/acre during the whole night) and take a longer time from lighting to reach efficient heating.

Blowing heated air into the fruit plantation using various types of *wind machines* does not prove economical. The hot air tends to rise, with the result that the area heated becomes too small. Wind machines alone using the heat of the inversion layer do not provide adequate protection. They can only be used profitably in conjunction with heaters placed in the plantation. They do, however, permit both later lighting and a reduction in the number of heaters required.

Sprinkling

Sprinkling, though relatively more efficient than heating, can only be used where a large water supply is available and where the soil is sufficiently well drained to withstand the extra precipitation. It is most economic where summer irrigation is also required, as the same equipment can be used for both purposes.

The orchards we visited in France and the vineyards along the Rhine had these favourable conditions but at present in France only the progressive growers use sprinkling (Figs. 2 and 4). It is more widely used in the vineyards of the Rhineland. A river or pond is usually the source of water, but in some orchards, underground water is used directly or pumped into a reservoir. Various types of pump are used ; in permanent systems, submerged electric pumps or Diesel engined centrifugal pumps and in mobile systems, tractor driven pumps. Permanent underground or overhead pipes (Fig. 6) are mainly used in the intensive orchards of the Paris region and in the vineyards of the Rhineland, and portable pipes are used where the same equipment is also required for summer irrigation of other plantations (Fig. 4).

Various types of impact rotary sprinklers are used for frost protection, all aiming at one rotation per minute and a precipitation of about $\frac{1}{10}$–$\frac{1}{8}$ in. per hour.

In the Rhineland growers sprinkling for frost protection in vineyards at the 'wool' stage of development encountered some difficulties. Buds had to be well wetted by sprinkling before freezing occurred, to prevent damage. The surface area of the buds at this stage is too small for the ice formation on them to provide sufficient direct heating to give adequate protection from frost. This problem is similar to that of the early stages of development in black currants, where higher precipitations must be applied to obtain protection.

Great importance is attached to the decision when to *start sprinkling* and no automatic device in this connexion is as yet even considered.

In Germany, sprinkling for frost protection starts and stops at 32° F measured by an exposed thermometer at the height of the crop protected. It was thought that a reduction in time of sprinkling could be achieved by the use of the recently improved Frosterkennungsscheibe (Freezing indicator) (Fig. 5). This consists of a horizontal circular metal tray 20 cm (about 8 in.) in diameter with a 2 mm (about $\frac{1}{12}$ in.) high rim. The surface of the tray is painted matt black and is covered with a film of water supplied by a wick from a container above. It is suggested that frost protection should begin at the time of ice formation on the tray and finish when it melts. There is, however, controversy about the usefulness of this indicator and we consider that it is not sufficiently sensitive.

In France, sprinkling used to be started when the air temperature at 16 in. was 32° F and stopped when all ice on the plants had melted. This, however, resulted in excessive amounts of water being applied (20 in. in 2 months). It is therefore now advised to start and stop sprinkling at 1·8° F above the critical temperature of the protected plant. Mr. Durand has determined the critical temperatures for fruit tree buds at various stages of their development, at Versailles. For apples these are 14° F before bud burst, 26·6° F at pink bud and 28·8° F at full bloom. There are difficulties in determining the critical point, which not only changes with the variety and its stage of development, but also with the degree of hardening acquired during the period preceding frost.

Artificial fogs

In spite of their ineffectiveness, fogs are still favoured in some vine regions because of their cheapness and ease in use. In order to form an efficient screen the area protected should be very large, the fog of much higher density than used at present, and the fog particles about 10μ in diameter. This would make them even more objectionable and they would still not protect the plantations from an inflow of cold air.

General

Cultural treatments are also recommended to diminish the risks of frost damage, e.g. keeping the soil compact and clear of weeds and postponing mulching and strawing until after the risk of frosts has passed.

At Montpellier it was found that the risk of frost damage to *vines* may be reduced by a January spray with 800–900 p.p.m. of NAA, which delayed the blossoming by 2 weeks.

Future developments

In France frost protection of many fruit plantations is a necessity and there is a future for the expansion of the sprinkling method of protection. By following the example of growers who are using sprinkling and heating side by side in adjoining orchards, others could gradually replace oil heating with sprinkling, especially where fruit plantations are grown on soils which would withstand the high precipitation and which require summer irrigation. This applies not only to southern France but also to the Loire Valley, where June and July droughts are frequent. In the Rhineland this method of frost protection is already being used on an ever increasing scale.

The main objection to sprinkling is the large amount of water required. This would be reduced considerably if light frosts, which never reach damaging point, could be forecast with complete accuracy, so that growers could avoid sprinkling on such occasions. The amount of water can also be reduced by taking advantage of (1) the supercooling period during which no damage occurs or (2) the critical temperature above which no killing takes place. In the first case one should start sprinkling before the state of supercooling comes to an end, and apply sufficient water to keep the flower above its freezing point. In the second case one protects from killing only, running the risk of superficial russet blemishes, which may, however, lower the fruit quality.

Summary

Some general aspects of fruit growing in France, and methods of spring frost protection in current use in France and the Rhineland are discussed.

PROGRESS IN RESEARCH ON FRUIT CROPS IN 1961

By B. F. SELF

Some items of special interest in the reports of the Research Sections are presented in this article for the information of fruit growers.

Rootstocks

Malling-Merton demonstration plots

The Malling-Merton rootstock demonstration plots are sited in different parts of the country on a variety of soils. They are intended to compare the behaviour of the new stocks grown under a range of conditions to supplement information obtained from experiments at East Malling.

The reports following the wet winter of 1960-61 have clearly demonstrated the value of these trials (p. 7). About a third of the trees on MM.104 and MM.109 on eleven of the thirty-two plots were seriously affected by waterlogged conditions. Growers should not use either of these two stocks for planting on any but perfectly drained land. Apart from this damage experienced with particular rootstocks, there was also a difference associated with the scion variety. More trees of Worcester Pearmain were affected than of Cox's Orange Pippin.

Cherry rootstocks

There is only one clonal cherry rootstock, Mazzard F 12/1, in commerce. This stock has many good qualities but some consider its great vigour a disadvantage. Very few of the dwarf cherry species have proved compatible with our commercial varieties. At East Malling the search continues for suitable stocks of limited vigour which are resistant to bacterial canker and compatible, and give satisfactory nursery performance (p. 8). Many crosses between *Prunus* species, Mazzard seedlings, and clonal rootstocks of differing vigour have been made during the last few years. About a tenth of all these crosses have survived two inoculations with bacterial canker and are being vegetatively propagated for further trials.

Some double-worked cherry trees are being prepared with interstocks, intermediate stem-pieces, of a more dwarfing rootstock, or species, grafted on a Mazzard rootstock (p. 8). It is hoped to combine the root anchorage of the normal Mazzard rootstock with a dwarfing effect given by the intermediate.

Propagation

Hardwood cuttings

A preliminary report was given last year of budding hardwood cuttings of plum rootstocks in the same year as planting. Similar success has been obtained this season (p. 8). The cuttings, up to 24 in. long, are taken from special hedges in the autumn, treated with a growth substance and stored in insulated bins. They are planted in the spring and subsequently budded in the summer on the original cutting stem. Maiden trees produced by this method are similar to those produced in the usual way on rooted layers. Although this technique can be used successfully with plums it cannot yet be recommended for apples.

Time of budding

When bud ties constrict the rootstock some variation in the growth of maiden apple trees occasionally results. This is sometimes associated with early budding, since the rootstock swells more in early July than late August. With early budded trees, it is wise, therefore, to release the tie early or use a material that is readily stretched (p. 8).

Root investigations

Roots are a considerable part of a fruit tree. Although many studies on root growth and distribution have been made at East Malling in the past there is still much to learn about the seasonal behaviour and functioning of roots.

In 1961 the construction of a large underground root observation laboratory was completed (p. 8). The laboratory is 96 ft long and contains 48 plate glass windows through which roots can be observed.

Some of these panels can be removed and replaced after experimental treatments. Unlike the older root observation trenches, which were constructed alongside existing orchard trees, bushes and young trees have been planted near the sides of the root laboratory. Black currants, plums and four-year-old trees of Worcester Pearmain on MM.104 all produced a large amount of new root in their first season after planting. Obviously there is a vast amount of recording to be done, not only on the growth of the plants, but also of soil moisture and temperature. Many photographs, some through a microscope, have been taken to supplement the measurements of root development.

Spring frost damage studies

An exceptionally late spring frost (27th-28th May) caused an unusual form of damage to young fruitlets—an internal browning (p. 11). Many of the damaged fruits dropped, but others grew on, with a brown mark round the core. Water sprinkling protected fruits from all damage, including internal browning. The equipment used at East Malling in this experiment is automatic and performed satisfactorily.

Further trials have been made with the use of gibberellic acid on frost damaged pears (p. 12). This substance, originally isolated in 1939 from a fungus disease of rice in Japan, has growth regulating properties. It has been applied in many parts of the world on a range of crops with a variety of responses. At East Malling gibberellic acid has been found to increase the crop of pears following frost by stimulating the development of seedless fruits. In the variety Conference, treated fruits were better in shape than the seedless fruits that this variety often produces after frost.

Growth and fruiting studies

Staddle forming

When F 12/1 cherry rootstocks are cut back one year after planting, the upper buds on the resulting shoots do not break out in the current season. It takes, therefore, another year to form a staddle, or branch framework, that is suitable for high-working with a cherry variety. Gibberellic acid, applied to the upper buds in 1961, did cause them to grow out but the branch angles were narrow (p. 17). Further trials will be made next year to see if this technique can be developed for use by nurserymen.

Effects of branch inclination

Many growers have found that horizontal branches, or shoots that are tied down, are less likely to make vigorous vegetative growth and more likely to bear fruit buds. Few critical experiments have, however, been undertaken on this subject.

A series of investigations has begun on growth, flowering and fruiting in relation to the inclination and bending of branches on young and established apple trees (p. 9). Some treatments include bending single branches, others are more extreme, such as the culture of young apple trees in upright, horizontal and inverted positions. Preliminary results suggest that changes in inclination affect the pattern of growth, which in turn influences flowering and fruiting. The results of these studies will be of practical value when applied to tree shaping and pruning techniques.

Biennial bearing

The fruits borne by the biennial bearing apple variety, Miller's Seedling, prevent the formation of flower buds. Does this influence vary according to the position of both the spur on the branch and the branch on the tree? The influence does in fact pass more readily down the branch than upwards. The spurs on the lower part of a branch are affected partly by the fruit they carry but also by the fruit higher up the branch and on other limbs of the tree (p. 9).

Soft fruit trials

Three years ago disc cuttings were made of seven clones of the strawberry variety Auchincruive Climax. The plants raised in this way remained green and apparently free from the genetical break-down called ' yellows ' for two years after propagation. Unfortunately, in 1961 plants of all seven clones showed ' yellows ' (p. 11).

Some years ago several strawberry varieties were freed from certain viruses by heat therapy. These clones were later shown to grow more vigorously than comparable untreated varieties and, with the exception of two varieties, Early Cambridge and Cambridge Rearguard, to crop more heavily. A

trial now in its third year confirms this finding (p. 10). Heat-treated plants of Early Cambridge, although larger, produce fewer flowers than those of the non-treated clone.

Breeding—Gooseberries

It would be very desirable to have commercial gooseberry varieties without spines. The breeding programme with this fruit at East Malling is concentrated on producing such types (p. 11). A Canadian plant breeder, A. W. S. Hunter, produced a number of semi-spineless gooseberry seedlings which produced rather small fruit. Some of these were later crossed at East Malling with large-fruited English varieties. Another source of spinelessness has been obtained from the black currant and some 2,000 flowers on a range of gooseberry varieties were pollinated in 1961 by a spineless black currant-gooseberry hybrid. Over 200 seeds were obtained. All the seedlings will be selected for improved fertility, fruit size, and mildew resistance in addition to spinelessness.

Weedkillers

The weedkiller, simazine, applied at 2½ lb and 5 lb of chemical per acre has been used without damage, or reduction in yield, on black currants and raspberries for the third successive year (p. 11). The usual commercial preparations of simazine contain 50% of the active chemical.

Nutritional studies

Irrigation

Since most of the fruit is borne on one-year-old shoots, black currant bushes are usually pruned severely to remove a proportion of the older wood. Where the growth is strong, as on bushes receiving irrigation or generous supplies of bulky organic matter, lighter pruning is desirable.

The effects of supplementary water on the growth and cropping of the black currant variety Amos Black have been assessed until 1959 on unpruned bushes. For the last two years part of the trial has been pruned normally. In 1961 the crop on the unpruned bushes was heavy, the irrigated treatments yielded the equivalent of nine to ten tons per acre and the unwatered nearly seven tons (p. 20). Although the crop was 40% less on the pruned than the unpruned bushes, the fruit was considerably larger.

Nitrogen

Until recently little was known about the seasonal levels of available nitrogen in the soil and when the roots take it up. Such information would be useful to growers when considering the rate and the time to apply nitrogenous fertilizer. Only a proportion of the nitrogen applied as fertilizer is taken up by the tree roots, some is washed down through the soil, particularly in cultivated orchards.

Some 700 soil samples, mainly from one apple orchard, were tested for ammonium and nitrate nitrogen throughout the year (p. 20). The lowest levels in 1960-61 were found from October to February, when rainfall, and consequently leaching, were high. Similarly, in a strawberry trial receiving nitrogen in spring and summer, the levels of nitrogen in the top soil in November were low and remained so until after the spring fertilizer was applied.

These studies are now extended to soils in black currant and raspberry plots receiving irrigation treatments and the effects of differing soil moisture regimes on the availability of nitrogen will be examined.

Ammonium compounds in the soil are changed by bacteria to nitrate forms, which are readily leached. When the soil is particularly acid the bacteria that perform this conversion process, or nitrification, are less active. This occurs on the acid soils of the Research Station, at Larkfield, and explains why a high level of ammonium nitrogen has been recorded there (p. 21).

Since it is often difficult in orchard conditions to know how much of the applied nutrients gets into the tree some experiments have been started, using potted apple trees growing in sand, to measure the response to the season of nitrogen supply (p. 21). This critical investigation will supplement a field trial already in progress at the N.A.A.S. Experimental Horticulture Station, Efford, in which three forms of nitrogen fertilizer are applied on dessert apples on six separate occasions during the year.

Magnesium

Five post-blossom sprays of 2% Epsom salt (magnesium sulphate) increased the number of fruits retained on the tree (p. 21). Three post-blossom sprays of magnesium chloride, which contains half the equivalent amount of magnesium as Epsom salt, had a similar result. In two separate trials,

these sprays of magnesium chloride were almost as effective as Epsom salt in preventing foliar symptoms of magnesium deficiency from appearing on extension shoots.

Although pre-blossom sprays of Epsom salt again prevented the early symptoms of magnesium deficiency on leaves on fruiting spurs of dwarf pyramid trees of the variety Edward VII on M.VII, this was not accompanied by an increase in fruit set. Similarly, when 0·5% urea was included in these sprays, there was no effect. Two pre-blossom sprays of urea used alone, however, tended to increase fruit set.

The residual effect of seven years of spraying with Epsom salt on apple stoolbeds has been examined (p. 21). Three sprays each year had only a small influence on the magnesium content and amount of interveinal scorch occurring on the leaves in the seventh year. In contrast, where nine sprays were used each season, the number and size of shoots was greater.

In previous years it was reported that where sprays of Epsom salt had been used on apple stoolbeds fewer shoots were attacked by mildew. Although these sprays have a small effect in preventing infection, a recent pot experiment suggests that mildew susceptibility is not directly related to the magnesium content of the plant (p. 22).

Insect pests

Raspberry beetle on loganberries

The most important pest on loganberries is the raspberry beetle. In the past both derris and DDT have been recommended for use against this insect. Malathion gives equally good control and also has the advantage of killing the leafhopper which is now known to transmit the virus disease, rubus stunt. Two sprays of 0·5% malathion, applied at mid-June and when the first fruits are just colouring, can kill both the adults and the larvae of the beetle. Recent tests indicate it is effective against the beetle eggs as well (p. 33).

Strawberry seed beetle

A substantial reduction in the damage caused by the strawberry seed beetle can be obtained by applying 5 lb of aldrin per acre on the soil around the plants immediately before strawing. This chemical leaves a less persistent residue in the fruit and soil, and is cheaper and more effective than the allied compound dieldrin. When fruits from plots that had been treated with aldrin prior to strawing were processed and tested by other research associations no effect of the insecticide on flavour was detected (p. 33).

Pest injury and growth

How much does pest injury to leaves affect the growth and activity of plants? Is growth reduced before signs of infestation are visible? These questions are being investigated jointly by some members of the Entomology and Plant Physiology Sections (p. 34 and p. 16).

Leaves bronzed by fruit tree red spider mites are not as efficient as healthy ones. It has already been shown that they are slower in taking up carbon dioxide and that they lose water more rapidly than unaffected leaves. In each of the past two years the growth of shoots and roots of potted Brompton plum rootstocks was seriously reduced following heavy red spider attack on the leaves. The results suggest that growth was checked before obvious symptoms of mite injury appeared on the leaves.

Bacterial diseases

Bacterial canker of plum

Bacterial canker often causes very serious tree losses in young plum plantations. It would be desirable to have a series of suitable rootstocks resistant to this disease. Reinoculations on 67 clones of selections of St. Julien of Orleans plum rootstocks have confirmed that 24 of these are highly resistant, if not immune, to bacterial canker (p. 24).

In a field trial with the varieties Victoria and Early Laxton, the rootstock Myrobalan B has again proved to be the most resistant to bacterial canker of the rootstocks now available to growers (p. 24).

Resistance of the rootstock to disease is not directly transferred to the scion variety but is useful to provide a resistant stem and crotch when a variety is high-worked on it. Sometimes the scion can affect the resistance of the rootstock. Stocks worked with the variety Victoria developed larger cankers than those with Early Laxton (p. 24).

Details of the life cycle of bacterial canker in plums are still imperfectly known. Unlike cherries,

infection does not occur through the leaf scars. The disease has been introduced into the tree through wounds on the trunk. Natural infection probably occurs through very small wounds. The rate of canker growth was greatest during the blossom period and then declined gradually and ceased by the end of May (p. 24). The trees are most susceptible to infection between November and January and inoculations in December produced the largest cankers.

Bacterial canker of cherries

Although Bordeaux mixture has been shown to be the most effective material for use against bacterial canker of cherries, it is an unpopular spray with cherry growers because of several disadvantages. Bordeaux mixture can damage the leaves in the summer unless used with the recommended quantity of cotton seed oil, which is rather expensive. Copper sprays also damage the spray tank and machinery. Laboratory and field tests are being made with a range of chemicals in the search for a suitable, safe, and efficient material against bacterial canker (p. 36).

Fungal diseases

Apple scab

Scab ascospore flights were detected in the Hirst spore trap in a Bramley orchard from the end of March until the beginning of May (p. 25). Some airborne conidia (summer spores) were observed later in the season.

It has been assumed that when there is a late season infection there will be a large number of ascospores released in the following spring. Although there was a heavy late infection in 1960, the number of ascospores subsequently caught was not correspondingly high (p. 25).

Apple mildew

Apple mildew has been a serious problem in many orchards in 1961. A bulletin summarizing methods recommended for the control of this disease appears on p. 122. Conditions are favourable for mildew infection when trees are growing strongly, producing many new leaves, and the weather is warm and humid. Infections have been recorded as late as mid-September on summer pruned trees. Sprays of DNOC/petroleum oil, applied in the dormant season up to the bud-swelling stage, reduce the number of overwintering infections in the buds. A close schedule of protective sprays until the end of June is essential to overcome a serious attack. In 1960 five sprays of 1% lime-sulphur or 0·025% dinocap (trade names : Karathane and Crotothane) gave better control of mildew on a hedge of a susceptible rootstock than a similar number of sprays of dinocap at lower concentrations (p. 26).

Lenticel rot

Recent studies on lenticel rot fungi at East Malling have been mostly concerned with the seasonal pattern of spore production. Control measures are being used to prevent fruit infection from the fungus *Gloeosporium album* already existing on the tree. Sprays of 0·1% phenyl mercury chloride (about 40 times the strength of a commercial PMC spray), applied before bud-burst on trees of Cox's Orange Pippin, reduced the number of spores produced in spring and summer (p. 26). The final number of lenticel rot infections on fruit from treated trees was considerably less than from the unsprayed. It would be undesirable to use this very strong mercury spray owing to its high cost and its danger both to operators and consumers. Experiments are in progress to test alternative chemicals which have a similar action.

Tree fruit viruses

Latent viruses

More knowledge is accumulating on the group of viruses, known as latent viruses, widely distributed in apple varieties and rootstocks (p. 29). These viruses show no obvious symptoms on commercial varieties and rootstocks and can be detected only in certain sensitive indicator plants. Some ornamental crab apples fail to grow, or make very poor growth, when budded or grafted onto a rootstock carrying these viruses. Fortunately for the nurseryman who grows ornamental crabs, there are several satisfactory rootstocks available that are free of latent viruses.

Rubbery wood

Branches of some trees of Worcester Pearmain have occasionally been reported showing a 'rubbery' condition. Grafting tests from certain stunted Worcester trees showing both the rubbery character

and swellings on the trunk indicate that they are infected with rubbery wood and flat limb viruses (p. 29).

Effect of virus disease on growth and yield

There are many trials at East Malling to study the effect of virus on growth and cropping. Reports have been published from experiments on apple and cherry, and other younger trials are now yielding useful information. In a pear trial, a common virus, vein yellows, practically halved the growth of four-year-old trees (p. 29). Similarly, in young plum orchards, the prune dwarf virus checked the growth of several varieties and markedly reduced the crop of Victoria and Marjorie's Seedling (p. 29).

Distribution of healthy material

In 1961 the rootstock Quince A was added to the list of healthy virus-tested material available for distribution to Members. This rootstock had been tested and found free of nine different viruses. Two scion varieties were released as Mother trees, the apple Egremont Russet M.152 and the cherry Roundel M.521. The latter variety is not considered completely virus-free but is the healthiest selection likely to be available for a number of years.

Since the Mother Tree Scheme began in 1953, 23 apple, 5 pear, 20 cherry and 10 plum varieties have been distributed to Members of the East Malling Research Association. A paper describing this Scheme appears on p. 125. The trees are intended to provide a healthy source of scion wood for propagation. They are the product of many years of selection and testing by pomologists and pathologists, followed by careful multiplication by the nursery staff. Some Mother trees at East Malling are allowed to fruit, and the fruits examined to see that no mutation or 'sport' has occurred. In 1961 budwood was collected from 140 cherry Mother trees, sent to nurseries between 1953 and 1955, to check if any have become infected since distribution.

Summary

Certain aspects of interest to fruit growers selected from the reports of the Research Sections for 1961 are presented in a popular form.

PROGRESS IN RESEARCH ON VERTICILLIUM WILT AND VIRUS DISEASES OF HOPS IN 1961

By R. V. HARRIS

This is the annual review for 1961 of items of special interest to hop growers in the general Research Report of the Plant Pathology Section (p. 24).

PROGRESSIVE VERTICILLIUM WILT

The increasing awareness of growers and brewers of the threat to wilt-sensitive varieties, such as Fuggle, through the spread of progressive wilt was reflected during 1961 by the sustained demands for allocations of certified stock of the wilt-tolerant W.G.V. through the Hops Marketing Board. The brewers also showed an increased interest in making trial substitutions of the newer wilt-tolerant varieties in their grist. In a year of generally short crops and a high level of quota acceptance, growers had every inducement to harvest with care every hop from their small trial plantings of such varieties. This worthy cause was further encouraged by a timely letter sent to them from the Chairman of the Association of Growers of the New Varieties of Hops. At the same time, the trial of the promising newer tolerant seedlings, not yet released, continued satisfactorily.

A high level of wilt-tolerance was maintained in the farm trials of three Wye-East Malling candidate seedlings

The three candidate seedlings are all being tried on each of three farms. In this the second season of these trials very high wilt-tolerance was maintained, and although the seedlings showed appreciably more wilt at one farm than at the other two, even here only 1, 3 and 5% respectively of their hills developed symptoms, compared with 6% of the W.G.V. hills planted for comparison.

The crops from these trials are being bulked for the first large-scale brewing trials by the Institute of Brewing.

Infection by the mild (fluctuating) fungus can produce wilt symptoms on tolerant varieties

In an experiment this year, plants of two highly tolerant seedling varieties from the Wye-East Malling series were inoculated with the mild fungus from a West Midland outbreak and, although most of these remained symptom-free, some developed slight but definite wilt. In the same experiment, plants of both the moderately tolerant OR55 and the sensitive Eastwell Golding, similarly inoculated, all developed typical fluctuating symptoms. Every plant in this experiment was afterwards shown to be carrying the mild fungus.

Large-scale pathogenicity testing in a glasshouse was successfully begun and carried to completion within the winter months

In the 1959 Review the discovery of a rapid glasshouse method of testing for the virulent fungus by means of mist-propagated cuttings was noted. This year we tried the method out on a large scale with some 27 samples of the fungus from West Midland outbreaks which we tested at the special request of the Ministry of Agriculture, Fisheries and Food. For this purpose a glasshouse was adapted with artificial lighting, polythene insulation and controlled heating, and one batch of samples was tested in November and another in February. Each test took only about three months to complete, a big saving of time compared with the two seasons needed with the ' concrete tanks '. The results, including those on a number of samples tested on both occasions, were on the whole clear-cut and consistent, and they can be regarded as conclusive and authoritative.

The concluding research on safeguarding machine picking from spreading progressive wilt showed that the safe composting of infected waste is a practical proposition

In the Reviews for 1959 and 1960 we reported from the first chapter of this research that the virulent fungus, whether living in the bine of sensitive or tolerant varieties, is highly resistant to destruction by heat.

The second chapter, noted in last year's Review (1960), concluded that even when an infected garden is ' rogued ' for wilt symptoms just before harvesting, many of the remaining apparently healthy bines will be carrying the fungus in them. This means that the fungus will be carried to the picking

machine, possibly scattered in bine debris en route, and will be ultimately thrown out in the machine-waste to re-infect other soil and plants. Stringent precautions against leakage in transit to and from the machine followed by total burning of all the waste were therefore advised.

But now, from experiments on ' the effect of composting on the infectivity of machine picked waste ', started jointly with the Department of Hop Research at Wye last year (1960), comes the third chapter and the climax of this investigation (on p. 102 of this Report). This concludes that if proper precautions are taken, not alone to avoid scatter in the transit of bines to the machine but to ensure complete destruction of the fungus in composting the waste, ' the advent of machine picking offers a greater potential opportunity for controlling spread than is possible when the hops are picked by hand '!

A programme of ' safe composting ' was arrived at by experiments with an enclosed and insulated composting heap sited immediately adjoining the machine house. The waste was delivered into this heap from a conveyor projecting from the picking machine directly over the centre of the composting enclosure. Infected bine fragments enclosed in nylon stockings were placed at varying depths throughout this heap and at these points temperatures were recorded periodically. It was found that the temperatures generated were sufficiently high to destroy the infecting power of 99% of these samples. The surviving 1% were situated near the surface of the heap, just under the insulating covering and even these could probably be eliminated by turning the heap at some stage.

Although this compost is relatively ' safe ' it should *not* be put on plantations of herbaceous crop plants, specially *not* on potato or strawberry or, of course, on land destined at any time for hops. If, however, it is returned only to grass orchards the risks of spreading progressive wilt should be virtually nil and certainly considerably below those in hand-picked gardens. For it is known that the peak of the invasion of bines, laterals and leaves by the fungus occurs when they are ageing, i.e. after harvesting. At this time, with machine picking all the bine has either been burnt or is in the compost heap. But with hand-picking it will remain coiled in position in the garden when considerable spread of the disease can occur before it is collected and burnt.

VIRUS DISEASES

In last year's Review two major advances in our research on nettlehead were reported in some detail and the launching of a further attempt to confirm the identity of the natural vector of mosaic was also mentioned.

During the present year work on both these major diseases and on split leaf blotch has continued and has given interesting results but these are neither conclusive enough nor of sufficiently immediate interest to the grower to justify reviewing them at this stage.

Progress with research on the less conspicuous hop line pattern virus was, however, definite enough to warrant reporting now

Paine in his search, some ten years ago, for the insect vectors of mosaic, infested healthy Petham Golding plants with two species of aphid previously fed on mosaic-infected Fuggle. Symptoms of both line pattern and mosaic then appeared on some of the plants and it was therefore concluded that the viruses responsible for both diseases had been transmitted by these insects.

In later experiments to test these conclusions, however, line pattern appeared again on the occasional hop plant, but this time also on some not treated with the aphids. It was therefore suspected that this virus might be more widespread than could be judged simply from the occurrence of symptoms on our native hop varieties.

An important step forward was therefore made this year when we found that the American hop, *Humulus americanus* var. *neo mexicanus* was an efficient indicator plant for line pattern.

And sure enough, in graft-transmission tests to plants of this indicator, hop line pattern virus was found in some Fuggle plants previously only known to be infected with a severe strain of split leaf blotch. Then three other Fuggle plants previously showing only nettlehead symptoms were similarly found to be infected. Finally, one further result in this connexion came from the field experiment on aerial versus soil transmission of nettlehead which we noted in the 1959 Review. Here line pattern symptoms were recorded this year, and these occurred exclusively on some of the plants with exposed roots but protected stems. This suggests that this virus was transmitted through the soil and provides, with the other two results, yet further evidence of more than a merely chance association of line pattern with the more destructive nettlehead and split leaf blotch diseases.

Summary

Items of special interest to hop growers in the Station's Report of research in 1960 on verticillium wilt and the virus diseases of hops are reviewed and discussed.

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Papers already accepted for publication in the current Volume 37 (1962) have been received from the main Horticultural Research Institutes in England, as well as from Australia and New Zealand, and contributions from other countries are being considered. As usual, a diverse selection of crops is covered, including apples, pears, plums, black currants, raspberries and vines ; spring cabbage, peas, glasshouse tomatoes, cucumbers and mushrooms ; tulips, carnations and stocks.

There are two studies of variation in apples and a report on a long-term nutritional trial on the same crop. Fruit storage, physiological investigations on apples and grapes, propagation of black currants, *Stereum purpureum* in plums and apple viruses are the subjects of other papers. On vegetable and flower crops there are reports on nutritional experiments, irrigation and the reduction of saprophytic contaminants in the carnation cultured-cutting test.

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